METALS and ALLOYS

The Engineering Magazine of the Metal-Working Industries

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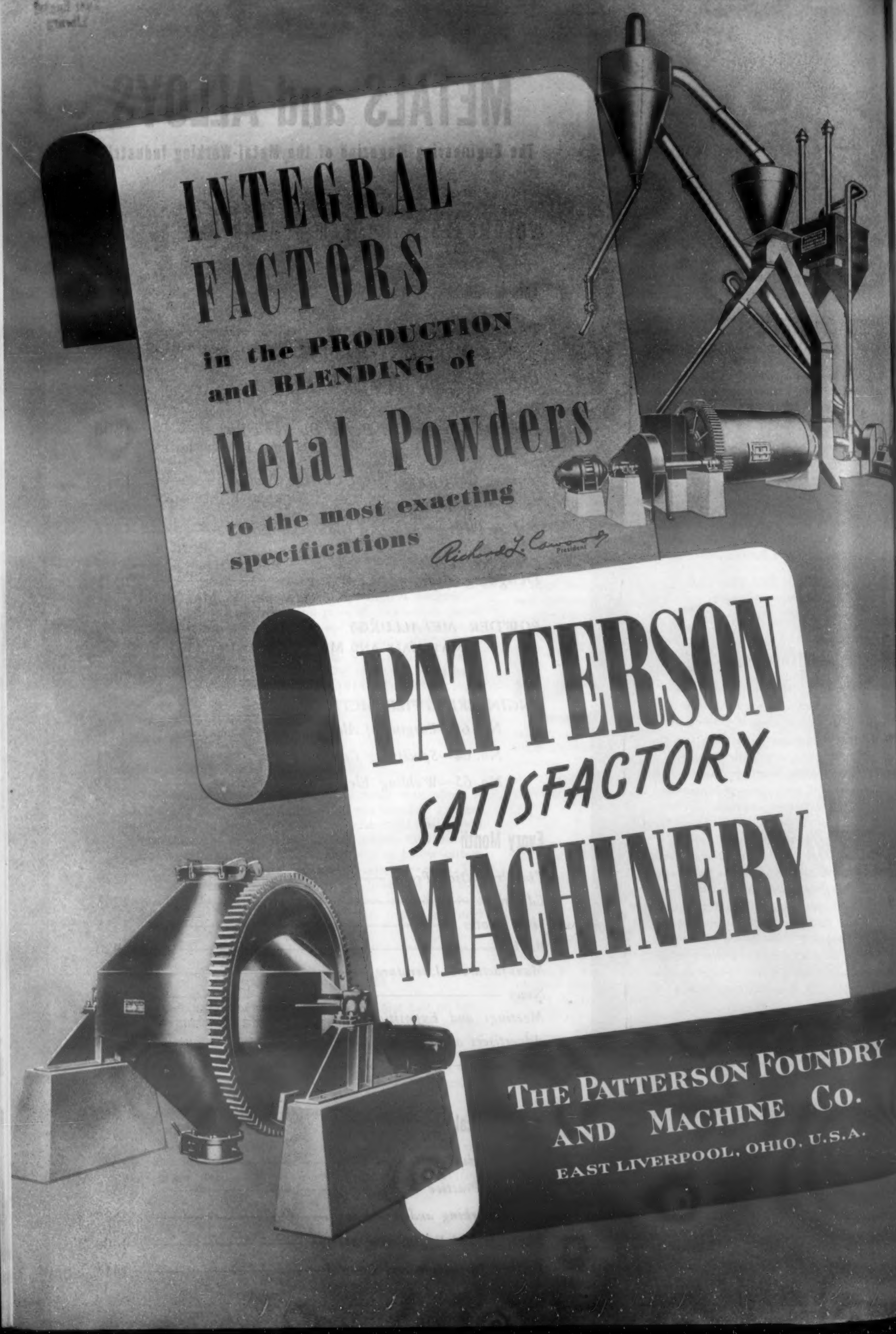
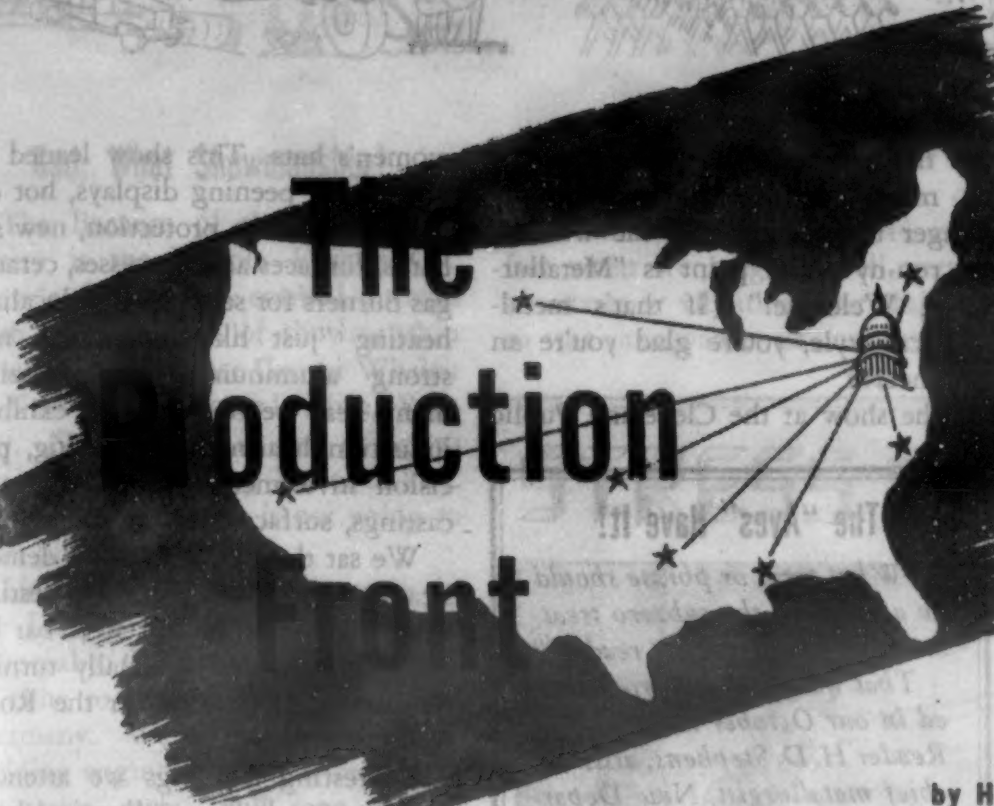
This Month

Every Month

Metallurgical Engineering Digest


INTEGRAL FACTORS
in the PRODUCTION and BLENDING of
Metal Powders
to the most exacting specifications
PATTERSON
SATISFACTORY
MACHINERY
THE PATTERSON FOUNDRY AND MACHINE CO.
EAST LIVERPOOL, OHIO, U.S.A.



The Production Front

by **Harold A. Knight**
News Editor

In 1942 we missed scheduled production 15%; in 1944, by 1½%. . . . We're straining to produce $5,900,000,000 of munitions monthly. . . . Certain critical programs lag 14 to 58%. . . . Government predicts 40% cut-back on V-E Day. . . . Shipbuilding to be cut 60%; aircraft, 20%. . . . Wide variations in cut-backs geographically. . . . Despite lopoffs we'll produce ahead of 1942.

Metal Show was breath-takingly big. . . . You noted modern trends in metal treating exhibited there. . . . We publish two suggestions for a name for sub-zero treatment. . . . Lincoln Electric Co. has a stupendous proposal! . . . Controls in some alloys after V-E Day. . . . How do you like our new series of cartoons?

Testing shells by sound waves. . . . However, there are some "bugs" to be Flit-ted out. . . . Three hundred potential technical articles from one company when "it can be told." . . . We rode on a military tank to observe the gun gyro stabilizer. . . . This gyro is merely a pilot—it doesn't do the work.

1942 the "Tool-Up"; 1944, "Close-Out," Year

The year 1944 has been the "most amazing production year in the history of the world," J. A. Krug, new head of the War Production Board, recently told a group of journalists. He classified 1942 as the "tool-up year," 1943, "the component year," and 1944 as the "close-out year."

In 1942, scheduled production was missed by 15%, but in 1944, by only 1½%. Last December had been our best production month, with $5,600,000,000 worth of munitions. But our schedule calls for $5,900,000,000 monthly by the end of this year. "The most difficult part of war production still lies ahead."

Certain critical programs are lagging behind, from 14 to 58%, among them heavy artillery, general purpose and fragmentation bombs, heavy duty trucks, superbombers and A-26 invaders.

A cut-back in production by 70% when Germany is defeated has been predicted by Alfred P. Sloan, Jr., chairman, General Motors Corp., which contrasts with 40%, or less, estimated by official Washington. The economists at the Capitol figure that 60% of the total cut-back will come during the first quarter after V-E (Victory-in-Europe) Day; 20% the second quarter, with third and fourth quarters 10% each.

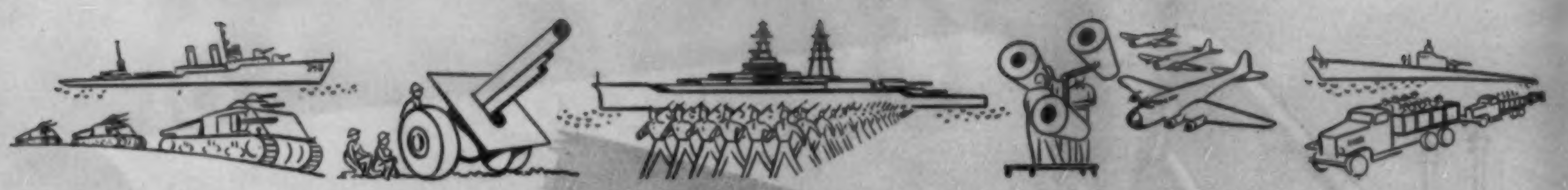
The shipbuilding program may be cut back 60%; aircraft, 20%. Ship cuts will not come fast, being mainly run-outs of schedules. Fast cuts will involve ground army procurement and aircraft.

Cut-Backs, Geographically

As to cuts, geographically, 50% cuts will occur in the Southeastern states and the Michigan automobile areas. Cuts in the South will be large because of prominence of the manufacture of ammunition and ships. The lop-off in the prairie states and the Pacific Northwest will be 25% because of production of big airplanes and combat-loaders, all needed against Japan. Cut-backs in cities will vary widely, some to be cut 85% because of concentrated war work.

Yet with all cut-backs, production will surpass 1942. The U. S. will still be spending $65 billion yearly. Not more than a quarter of our plants will need drastic revision for peace manufacture.

Priority controls of materials for civilians will be almost completely removed after V-E Day—except in chemicals, textiles and forest products.



Some Alloys Controllable After V-E Day

After V-E Day it appears that controls will have to be retained over production and allocation of some alloying elements, such as nickel, chromium, molybdenum and cobalt, in cases where there is short supply or where materials are used other than for steel making, according to John H. Stapleton, Distribution Branch, Steel Div., WPB, in addressing the Steel Mill Maintenance & Repair Industry Advisory Committee, WPB.

Steel industry members expressed themselves as being greatly concerned over the manner in which the V-E Day announcement will be made. Various committee members stated that they were trying to arrange with certain reliable employees to stay on the job when the announcement came so as to prevent damage to machinery and equipment that would result should everyone quit work. Blast furnaces must be kept in operation. Heats must be tapped from open hearths and electric furnaces. Soaking pits and heating furnaces must be emptied and the ingots, blooms, slabs, etc. finished. Widespread damage to facilities could result if provisions are not made to keep in the plant a minimum force to look after the essential operations that cannot be stopped at a moment's notice.

That Metal Show Monstrosity

Some 50,000 attended the National Metal Congress at Cleveland in mid-October, or twice those at the 1943 Chicago show. Men (and women) with Metal Show badges were bulging out of hotels, rooming houses, private homes and the lake passenger steamer, *Greater Detroit* (at $8 per bunk—night). You walked aimlessly down the streets to: (1) find a vacant table in a restaurant, and (2) find cigarettes. You eventually accomplished (1) but as to (2)—"No Cigarettes, Sorry" greeted you on signs at all tobacco stores.

On a back street you perhaps encountered an eating place—the name is vague in your memory, perhaps "Greasy Joe's." A cat is curled up on the counter. The grimy window is mostly opaque and hardly any longer translucent. On the window in run-ny white paint is "Metallurgists, Welcome!" (If that's metallurgical style, you're glad you're an engineer!)

The show at the Cleveland Public Auditorium is breathtakingly big—30 to 40% larger than ever before as to space and number of exhibitors. You marvel at the exhibit room underground and extending a third of a mile beyond the building itself. In some sections there are no straight aisles—you zig zag in a veritable labyrinth of booths.

There are styles in displays, as in women's hats. This show leaned towards shot peening displays, hot dip coatings for rust protection, new salt baths, furnaces and processes, ceramic gas burners for selective and localized heating "just like induction," new strong aluminum alloys, brazing, many heat treating furnace exhibits, induction heating and melting, precision investment and plaster mold castings, surface finishing and coating.

We sat through a Ryerson demonstration of Jominy hardness testing, watching the white hot steel bar being quenched and gradually turning to silver—then tested on the Rockwell machine.

Interesting meetings we attended were on trends in metallurgical heating, quality control, sub-zero treatments, surface peening, new aluminum alloys. The radiographers were out in force. Their little society bids fair to become an important factor in their industry.

Distinctly worthwhile was the meeting of the Metal Powder Assn., featured by a sincere and warmly stimulating talk by Dr. Leach, of Handy & Harman, on the past and future of powder metallurgy.

But, gosh! It's all too big to describe here. Tongues do wag and say it's all too big—that it should be exclusively an ASM show—leave out the other four. Readers, your opinion, please!

The "Ayes" Have It!

"What term or phrase should be applied to the subzero treatment of steel, gentle reader?"

That question we propounded in our October issue. Gentle Reader H. D. Stephens, assistant chief metallurgist, New Departure Div., General Motors Corp., Bristol, Conn., has been awarded the 2,000,000-volt X-ray for the best term, in the opinion of the editors. He not only presented a well-designed 9-letter word, but improved its physicals through shot peening done by Poetic Muse & Co. We present it in an "as is" condition:

"Normalize and spheroidize
Austenitize and carburize
So why not now extemporize
And coin a new word, 'Frigidize?'
Then all who read may recognize
A way to say Martensitize;
A process one can visualize
Who looks with metallurgist's eyes."

We suppose that hereafter the metallurgist's formula for success will be:

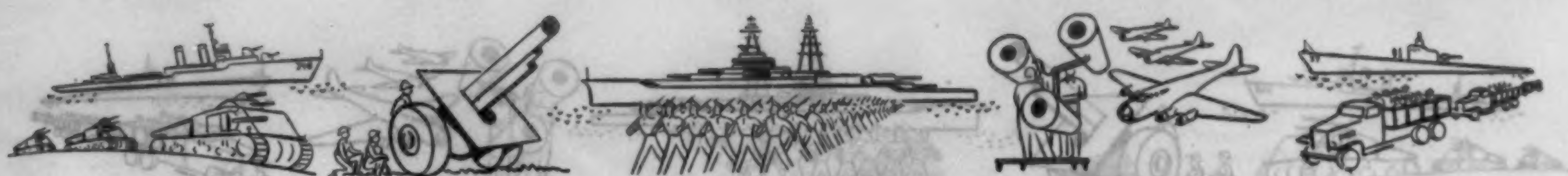
"Early to bed; early to rise—
Work like H—
And Frigidize."

"Cold Treatment"

Since writing the piece in the box on "Frigidize," which appears to the left on this page, we have received another name suggestion for sub-zero treatment of metals—this time from George H. Bierman, chief metallurgist, Amertorp Corp., Forest Park, Ill. He says:

"In the past we have always referred to heat treatment as any process where material was heated substantially above room temperature. Now it seems to me that the shortest general term for cold treating substantially below room temperature would equally well be covered by the term, 'Cold Treatment.'"

Well reasoned out and well expressed, George!



Gad, What Showmanship!

The Barnum of the welding industry is the Lincoln Electric Co., Cleveland, who have crashed through with as neat a bit of showmanship as we have seen since Grover Whalen of New York welcomed visiting Royalty. No, Lincoln is not going to straighten the Leaning Tower of Pisa. Guess again! No, he is not going to sand blast the Pyramids.

Lincoln would weld the crack in the Liberty Bell. He has made the proposal to Congress. He would do it in time to ring in the victory over Germany. W. J. Conley, Lincoln's welding engineer, with excitement in his voice, says: "Full tone can be restored by arc welding. The long-hushed symbol of liberty could again proclaim Liberty throughout the land by the miracle of radio. Congress might well appoint a committee of experts from the American Welding Society to take action."

Here are the essentials of suggested procedure. A ¾-in. hole should be drilled at the upper end of the crack over the crown to make certain as to the exact location of the end of the crack. Preheat the whole bell between 200 and 300 F. with burners inside the bell while welding outside. Mount the bell so that welding beads can be placed alternately, first from the outside, then from the inside to equalize shrinking stress. Since the casting is 20% Sn, peening must be controlled so that hammer blows will not injure the metal.

Carbon electrodes, ⅜ or ½ in., should be used in water-cooled holders so that larger amperage direct current can be applied. Filler metal should be 20% Sn-80% Cu, same as the bell. The bell weighs just over one ton, is 12 ft. in circumference around the lip, and 7 ft. 6 in. around the crown.

Not since experts cut the Hope diamond would there be so much tension during proceedings!

Testing Shells by Sound Waves

Occasionally a publication "rings the bell" in eliciting reader-interest far and beyond what the editor had expected. This happened to our publication in the June, 1944 issue. But when we rang the bell, certain overtones or vibrations were missing, to the annoyance of our readers.

STRESS RELIEF By GILBERT

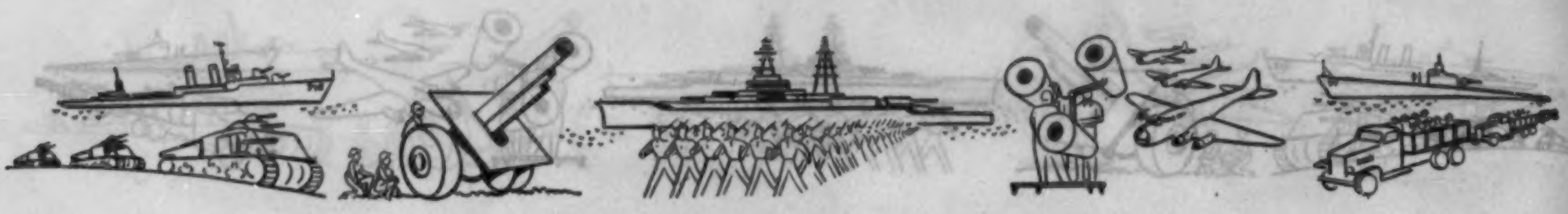
"It took time—but here's the female plug you asked for."

Many were the letters we received for further information. Because of this response and to supply in print the missing information, we publish this little piece.

A short article in our news section was headed, "Testing Shells by Sound Waves." An instrument, known as the "Sonotest," tests 20-mm. shells by an analysis of sound waves generated by striking or dropping the shell upon an anvil. It is sponsored by the Ordnance Dept., Army Service Forces.

The instrument distinguishes and measures the frequency of the sound wave, its amplitude and duration of the sound. The shell is bounced twice upon the anvil, first upon its base and then upon its side. Up to 1800 shells per hr. can be inspected. A green light indicates acceptance.

This news came to us from the War Department, Public Relations branch. The chief questions we were asked by many readers were: "Who makes this instrument?", and "Where can we get additional details?" We referred all letters to the Ordnance Dept. At length it dawned on us



that we ourselves better take steps to get more details.

In due time we received the following letter from a Captain, assistant to Major-General G. M. Barnes, Ordnance Dept.:

"This equipment is manufactured by the Vendo Co., Kansas City, Mo. A full description of how it operates is given in the 'Army Ordnance Journal' of January-February, 1944. At the present time this method of testing shells is not used by the Ordnance Dept."

Meanwhile we have received a letter from Alex Izzard of the Vendo Co., stating in part as follows: "For awhile several of these units were in use by ordnance plants testing 20-mm. shells by supersonic sounds emitted by these shells—the machine being set for frequencies given off by the good shells. Those which were cracked were rejected. However, as this instrument did detect only gross cracks and loose bands and not dimensional errors, the units were withdrawn for further development.

"To this date very little progress has been made in adopting this method to detect dimensional errors. We do not imply that the sonic method of testing is not applicable—but rather that we are still in merely the exploratory stage."

The device originated from attempts to find an automatic method of refusing bad coins and making change for bottled drink vending machines. Hence, the postwar application of this shell tester would seem clearly indicated.

Peace and the Technical Press

"How many potential technical articles on matters now secret does your company have up its sleeve?" we asked the head of the public relations department of one of our largest industrial companies recently. He scratched his head and wrinkled his brow, then came out with: "About 300. But the trouble is, you technical editors will not be interested because the war will be over and your readers will be eager for only peace techniques and production."

That expresses the crux of the situation among the technical press generally. The world will be war weary and will want to forget it all. However, a great majority of the improved techniques will carry over into peace. The smart editor will perhaps slant his article into peace channels, mentioning, perhaps casually and incidentally, that this was the method used in making shells, gun barrels, grenades, etc.

In short, the dove of peace will exude from the immediate postwar articles, but it will be noted that the dove has several strong likenesses to the war eagle—perhaps the eagle's beak and claws.

Tank Gun Gyro Stabilizers

A small boy would have given his best red yo-yo to have been where a group of us were—riding in and on a light military tank on the proving ground back of Westinghouse's Springfield, Mass. plant. Holding on to any handy rail or knob, in typical street-car-rider style, we charged the target, yelling: "Hitler, here we come!" It was a demonstration by Westinghouse of the marvelous tank gun gyro stabilizer.

At 15 mi. per hr. over typical terrain, the device provides 70% hits from 1200 down to 300 yd.; without the stabilizer, under 1% hits result. Formerly, of course, tanks stopped to shoot. Now we fire on the run.

In operation, six fundamental functions are performed when the tank pitches: (1) the gyro control is slightly displaced from its former vertical position; (2) the resulting precession of the gyro makes electrical contacts, shortening resistance through the "silverstat" (or rheostat); (3) the changed current alters the two electro-magnets regulating the teeter valves; (4) the operation of the oil valves decreases the pressure on one side of the hydraulic piston (fastened to the gun breech) and increases the pressure on the other side; (5) the piston is forced toward the low pressure side; and (6) the movement of the gun is controlled accordingly, since the piston is fixed to the gun.

The stabilizer not only satisfied field conditions but surpassed original requirements. In general terms, the result is the stabilization of a component mass with respect to space when mounted on the principal, moving mass. To Clinton R. Hanna, Westinghouse research engineer, goes most of the credit. He started work on the stabilizer in 1939, and it was first put to use in 1942. Every U. S. tank overseas is so equipped, and units are being supplied to Britain and Russia.

The gyroscope holds movement of the gun to only 1/16 in., up or down. In 1936, Mr. Hanna invented a device to equalize the speed of roller motors in a steel mill. A postwar application may be stabilization of railroad cars and automobiles by gyroscope, about 3 h.p. being needed.

Mr. Hanna based his device on Sir Isaac Newton's "First Law of Motion," formulated in the 17th Century. Thus, every body continues in its state of rest or uniform motion in a straight line, unless it is compelled by force to change that state. According to that law, the gyroscope has the tendency to maintain its direction in the axis of rotation.

We asked a foolish question: "Why not stabilize the entire tank for the comfort of the crew and accuracy of firing?" "Because the floor of the tank must rise and dip with the terrain—otherwise it would not clear obstacles," we were told.

There is an important difference between this gyro and that used to stabilize ships. In the latter, the gyro does all the work, meaning massive flywheels and weight, often considered dangerous as the massive metal might chunk off under the terrific centrifugal force, break the ship and injure passengers. The tank gyro is merely a pilot, with other equipment to exert the stabilizing force. Hence, this gyro is much smaller—about 8 in. in diam.

We hear the Germans tried gyros on submarines, actuating dorsal fins, rudders or flat surface stabilizers—but not very successfully.

Materials and Methods: One Problem, One Publication

If the war has revealed anything about the engineered production of manufactured products like aircraft, ordnance, motor vehicles, electrical equipment, machinery, castings, forgings, and similar things, it is (1) that the key factors in most efficiently obtaining the best possible product are the *materials* of which it is made and the *methods* used to process and fabricate those materials into the finished article, and (2) that these two factors—engineering materials and processing methods—are increasingly so interwoven as to become inseparable from the engineering point of view.

The first conclusion—that *materials* as such and *methods* as such are the most important engineering elements that affect product quality and production efficiency—is not new to most thoughtful observers of manufacturing trends in the past 20 years. For example, without such *materials* as alloy steels, strong aluminum alloys, plastics, stainless steels, high-strength cast irons, special zinc alloys and engineering bronzes we could have had nothing like the automobile engines, fast aircraft, transparent bomber noses, acid-resisting pumps, machine tools, die castings and rust-free bolts that we do, to name only a few. Similarly such innovations and improvements in *methods* as welding, carbide-tool machining, continuous rolling, centrifugal casting, powder metallurgy, injection-molding and infra-red drying have speeded (in some cases have even permitted) the production of ships, machine-parts, steel sheets, cannon, self-lubricating bearings, ammunition rollers and soldier's helmets.

But the second observation—the close interrelationship between materials and methods and their emergence as a single problem that depends on a single individual, or a closely-knit group of individuals in a given plant for its solution—is only now becoming generally recognized. Actually it is seldom possible today to specify just the *material* for a particular product. The engineer must also indicate the *method* by which it is to be fabricated. This choice in turn must be based on the processing equipment available in the shop, and on the workability of the material by that method and on that equipment.

And on the other hand the production engineer or technical operating executive—the methods man—must know his *materials* as he never did before. The very existence of such terms as machinability, hardenability, weldability and forgeability reflects this fact. If the material choice was poor from his standpoint, his production operations break down and rejections or low output result. He has to change his heat treating cycle or even his basic process or atmosphere if there is a change in material; every material being machined requires its own speed, feed and rake angle; some metals are easily electroplated, others necessitate special baths, setups or intermediate layers; certain types of forging presses or hammers are better for light metals and others for steels. *There is no such thing as a standardized processing method applicable without change to many materials, nor a single material that is so fool-proof as to be workable in every processing method or type of equipment in which it is tried.*

Beyond all that the engineer knows that the ultimate properties of the material in his product may often depend completely on the processing methods—*e.g.* heat treating, shot peening, surface coating, weld effects, forging, etc.—applied to it. And conversely

he knows that the material requirements may dictate the choice of method (as with Vitallium precision castings or electrical contacts by powder metallurgy), or that a narrowing of method to those few that can handle the geometric shape of the part also narrows the material-choice to those materials that are amenable to these methods.

In a nutshell, the choice of engineering material profoundly affects the processing methods used, and on the other hand the choice of processing methods and equipment can make or break the material's final performance. The two choices are therefore more and more being made by the same man or group of men in close consultation. Recognizing this and sensitive to its obligation to keep editorially abreast of broad trends in its field, METALS AND ALLOYS will increasingly concentrate (as it has tended to concentrate for the past few years) on the single broad field represented by ***engineering-materials-and-processing-methods***. We will specialize more and more in helping engineers and technical production men in the metal-working industries to solve the problems of "What material shall I use?" and "What manufacturing or processing methods and equipment are best for a given material or job?" We will analyze and present our editorial material from that viewpoint and wherever possible develop and interpret the tie-up between materials and methods as we see it.

There are many excellent magazines serving the metal-working industries—some concerned primarily with design (including materials), others with plant production methods, others with metallurgy. METALS AND ALLOYS because of the inevitable convergence of these interests now crystallizes and redefines the editorial policy it has been shaping in recent years—a policy of correlating the functions of design engineering, production engineering and metallurgical engineering involved in the selection of engineering materials and processing methods in the metal-working industries.

—F. P. P.

Steel Quality in One Man's Lifetime

A grand old man we know recently died at the age of 80 after a full and panoramic career in the iron and steel game. He had lived during, and to some extent worked with, three successive stages of steel metal inspection and classification practice. As a boy of 14 he frequented the docks where he broke up and classified pig iron just arrived from Scotland. He graded the iron by the appearance of its fracture. After apprenticeship on the docks, he donned long pants and took trips up the Hudson to sell pig iron to the many small foundries that dotted the Hudson's shores. But that is another and interesting story.

At the time that this g.o.m. was squinting at prosaic pig iron fractures, other men of the horse and buggy days were at the Bessemer plants, deciding when enough blast had passed through the converters by the exact shade of color issuing from the converter's mouth. In short, grading of iron and estimates of completed Bessemer heats were entirely rule-of-thumb, dependent entirely on the well known "human equation."

Time passed and the g.o.m. no longer graded the iron by fracture. His customers were now chemistry-wise and they ordered their pig iron according to percentages of silicon, sulphur, phosphorus, etc. Steel and other metals were being ordered now by chemical analysis.

But this g.o.m., who attended yearly meetings of the American Iron and Steel Institute, learned during his closing years at the technical sessions and through technical publications and the gossip of the trade of the No. 3 technique—the specifying of iron and steel by its indicated performance, with disregard for chemical composition. He heard of Jominy tests and TTT curves.

Meanwhile g.o.m. had learned that the human eye is no longer depended on to gage the end of the Bessemer process. The electric eye, or photoelectric cell, does that more accurately.

Probably there were times when g.o.m. suffered twinges of homesickness for the good old days. Much glamor, gambling, and reputation for skills have passed. Steel and the metal-working industries have become coldly scientific. Yet who would really want to go back to grading pig iron by fracture?

—H. A. K.

Reservoirs of Vital Minerals

Possible rapid depletion of our reserves of strategic and other war materials, should the present war continue indefinitely, is a source of no little thoughtful anxiety for many close to the metal industries. The present consumption of iron ore, steel, copper, lead, zinc and so on is beyond the realistic comprehension of the average citizen. It is not beyond the realm of possibility that new sources for some materials outside our borders may have to be sought.

In this connection we read recently, in one of the *Industrial Bulletins* of Arthur D. Little, Inc., the following paragraph which interested us keenly:

(Continued on page 1326)

Lead coatings often see front line war action. Here a walkie-talkie is lead-coated, the action being at Bougainville. Tanks had been called on to knock out Jap positions. Signal men in the foreground are giving a blow by blow description to headquarters.

Lead Coatings on Steel

by HAROLD A. KNIGHT *News Editor,* METALS AND ALLOYS

THOUGH LEAD COATINGS have been promoted during this war to save more critical metals such as zinc, cadmium, chromium and tin, and hence might have the somewhat degrading standing of a mere substitute, lead coatings are found to have considerable merit and for many uses do not have to be relegated to second place.

As Clinton H. Crane, president, St. Joseph Lead Co., said in a speech last spring: "All matter is composed of electrons whirling around protons. Each particular molecule is more suitable for some certain purpose than any other." Apparently those who have worked in the development of lead coated steel have faith that the lead molecule, as armor to the various molecules in steel, has a good future.

The lead or lead alloy coating over a properly produced base metal (a pioneer producer uses special analysis low carbon open-hearth steel) possesses a high degree of workability, withstanding severe deformations without injuring the coating, due largely to the soft and ductile lead. Lead covered sheets solder easily and rapidly with less than the usual consumption of solder. Since the lead is an effective lubricant (witness deep drawing of steel shell cases),

it is effective in die forming, stamping and spinning.

Lead does not corrode or weather away through galvanic action when in contact with steel. Sheets spot weld fairly readily, at least where smaller electrodes and higher current density than usual are employed. It takes and holds paint and synthetic enamels without priming coat and without any preparatory treatment other than usual removal of dirt and greases. Lead-coated steel is especially well adapted for heat duct work as the coating does not flake or scale off when heated. In certain places, such as wet battery clips, it maintains uncorroded electrical conductivity longer than other metals. Applied to bolts, it has a gasket effect and holds bolts tight into place.

In the prevailing hot dip method of application fuel costs are low due to low temperature needed and there is little dross loss. Damage to pots is negligible. Pig lead is the cheapest of coating metals. When electroplating with lead an important consideration is that the electrochemical equivalent of lead is the highest of any common metal except silver and gold. Thus, at the same current densities, lead deposits will be more than twice as thick as zinc when plated for the same length of time—and thick plates are practical, at least from the cost standpoint.

In the case of the lead alloy of the National Lead Co., No. 560 (low tin and antimony), the alloys become harder with age, increasing from 12 to 20 Brinell (500 kg.) after two or three days at room temperature. This makes for good abrasion and mechanical injury resistance. Elongation values approximate 39%. The tensile strength of chemically pure lead is 1800 p.s.i. whereas that of No. 560 is 6500 p.s.i.

On the other hand, lead coatings have their limitations, too. The Continental Steel Corp., Kokomo, Ind., which has been experimenting with lead as a coating metal for steel for 12 yr. frankly says: "'Lead-Sealed' sheets are *not* recommended, at present, for food containers; for roofing, unless painted; where water is gathered for drinking purposes; for laundry equipment or for other applications where intermittent use of steam or hot water is encountered. Experimental work is being carried forward to develop further facts regarding these and other possible uses for this product."

Examples of Applications

The National Lead Co., which is in the forefront of the lead coating development and which has done a good job in organizing and assembling its information, lists a "few examples" of uses for lead coated materials:

I. General: Gasoline tanks, radiators, barrels, drums, cans, oil containers, laundry machinery floats, boat brackets, sheet and strip.

II. Agriculture: Fencing, farm equipment.

III. Air Conditioning: Ducts, convection coils, heating coils.

IV. Electrical: Small radio parts, radio housing, pole line hardware and battery handles and parts.

Usually hot dip coatings of lead alloys have been limited to the so-called terne alloys, composed of lead and from 18% to 25% Sn. The use of electrodeposited lead as a protective coating first came into prominence during World War I, where its unique chemical resistant qualities made it adaptable to lining of gas shells, boosters and other parts in contact with chemicals. After the war in this country lead coating declined to certain specialized uses, particularly where resistance to sulphuric acid was desired. However, in Europe lead coated steels have been used much more widely than here.

A MATERIALS ARTICLE

A leading wartime development in the metal-finishing field has been the evolution and wide application of lead alloy coatings for steel. Originally a conservation measure to save tin, zinc, chromium, etc., lead coatings (especially certain specially formulated lead alloy coatings) have often proved superior in their own right and lead coated steel has thus become of outstanding interest to designers seeking economical, easily workable and corrosion-resistant materials for many types of post-war products. This article describes the coatings (both hot-dipped and electrolytic) and discusses their engineering properties and applications.

—The Editors

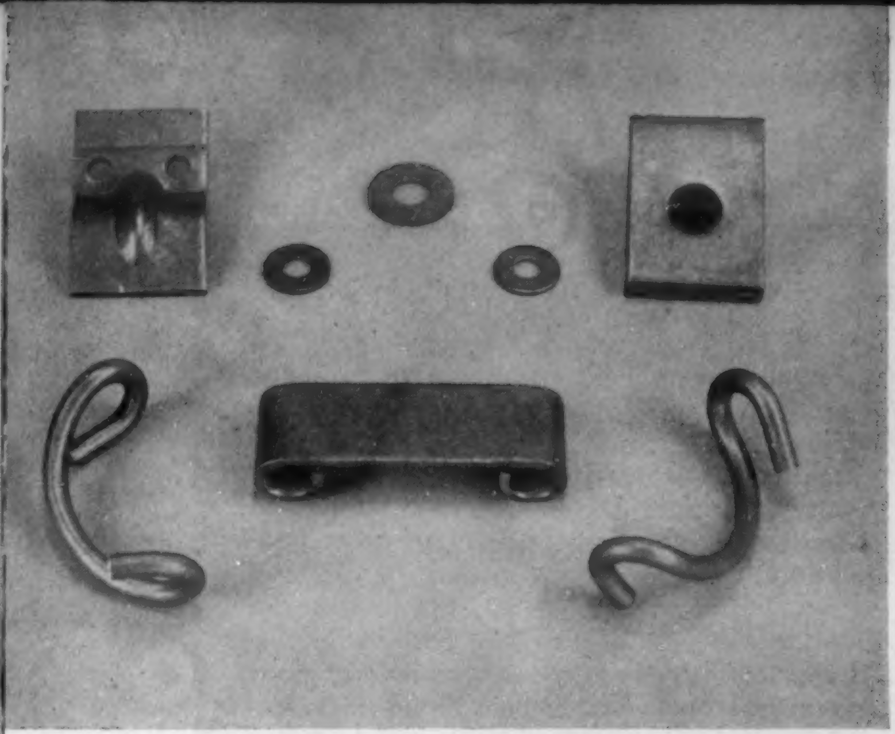
Thus such coatings are used on structural members in the building of railroad stations, tunnels and bridges and on railroad screws, bolts and nails. The German State Railways specify exceedingly thick coatings on structural parts which have to stand up in this very severe service—a coating 0.012 in. providing an expected life of 10 to 20 yr. against 3 to 5 yr. for the best paint coatings. Switzerland uses this material widely, such as at power stations and on transmission equipment, structural parts for factories, foundries and chemical plants. Thicknesses of coatings vary from 0.008 to 0.12 in., the last for chemical uses.

Classifications—Materials, Methods

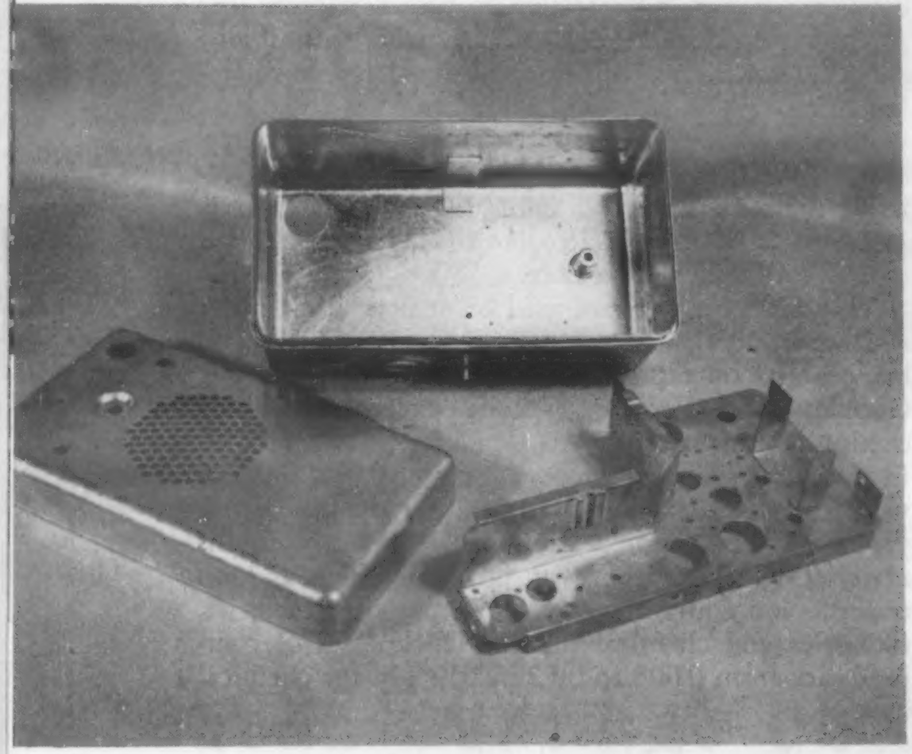
In the United States lead coatings fall into two divisions, no matter what classification one has in mind: First, there are commercially pure lead coatings, such as applied by the Western Electric Co. in making pole line hardware, 60% of which is now being pure-lead coated; then there are the more common lead alloy coatings, containing one or more of the following: Tin, antimony, silver and zinc.

Again, first there are the hot-dip coatings, where recent developments have been the more publicized and then the electrodeposited lead.

The National Lead Alloy No. 560 is described as containing 95% Pb and 2½% each of tin and antimony. The American Smelting & Refining Co. produces "Plate-Loy," containing: Sn, 2 to 2½%; Zn, 1%, and Sb, 1%, added to commercially pure lead. The Weirton Steel Co.'s coating contains: Sn, 2 to 2½%; Sb, 2 to 2½%; Ag, 0.25 to 0.50%, using as



Western Electric was one of the first to use lead coatings for telephone pole line hardware. Here the coating material is commercially pure lead, though usually a lead alloy is used.



Power pack cases and radio chassis of fabricated steel lend themselves well to such coatings.

a base either hot rolled or cold reduced basic open-hearth steel sheets of, say, 0.10 max. carbon.

The silver has a particularly happy affinity for the tin and enhances the bonding qualities of the coating, in the opinion of Alex Stewart of the National Lead Research Laboratories. It adds to the adhesion qualities of the coating, promotes wetting and, most important, it adds to corrosion resistance.

The tin provides wetting, among other imparted qualities, though electroplated lead requires no tin for coating steel. Bruce W. Gonser, Battelle Memorial Institute, states: "We are currently advocating relatively high antimony content, such as a lead base with 8 or 9% Sb and 1% Sn. The high antimony gives increased hardness, better resistance to weathering under hot humid conditions and somewhat better appearance."

Chief Blemish—Pin Holes

One with only a casual knowledge of lead coatings immediately calls to mind the much publicized "pin holes" in the coating. However, all authorities apparently agree that if the coating is of proper thickness, say 0.0005 in., "pin holes" are not inimical to corrosion resistance. Apparently "pin holes" are self-healing. There is formed some kind of lead-iron oxide compound that resists further corrosive action. In fact pure lead itself oxides and immediately the film of lead oxide seals off against further corrosion just as happens to several metals, notably aluminum and copper, the oxide of the latter being known as "patina."

If pin holes exist the iron in the base metal oxidizes from the ferrous to the ferric form, according to Alex Stewart, which places the iron in a better condition to affiliate with lead to prevent further corrosion at the pin hole area. It is best to have a coating at least 0.0004 in. thick to provide sufficient alloy for the chemical combination with the iron.

States Dr. Lyman J. Briggs, director, National Bureau of Standards: "In industrial atmospheres, evidently because of the sulphur-containing gases present, the 'pin-holes' are quickly sealed by the resulting corrosion products. In a less polluted atmosphere, the corrosion product from underlying steel serves the same purpose and the coating is apparently much more protective than its appearance might indicate."

The Continental Steel Corp. says: "By the 'Lead-Sealed' process these 'pin holes' have been reduced to a minimum, and it has been discovered that the brown discoloration is almost entirely on the surface of the lead coating and eventually disappears when the product of the lead and iron seal these small openings. The lead alloy coating remains to protect the underlying steel sheet for many useful years and does not disappear in the same manner as some of the so-called 'sacrificial' metals."

Albert J. Phillips, Research Dept., American Smelting & Refining Co., comments: "With pure lead it is difficult to get a coating 0.0005 in. thick and it is our contention, all other factors being the same, that the heavier the coating, the better the protection, particularly with regard to 'pin holes.' Even the best lead coating contains 'pin holes' and these, under many types of exposure, become stained due to rusting of the base metal. Frequently on the basis of a cursory examination, lead coated steel parts have been condemned because of the appearance of this stained surface. Detailed examination frequently shows that the discoloration does not indicate a serious degree of corrosion of the base metal and the reaction frequently stops after a short time, possibly due to plugging of the 'pin holes' with the products of corrosion. Usefulness of lead coated articles, in spite of 'pin holes,' has been demonstrated amply and it is anticipated that as the public becomes acquainted with the properties of this material, further uses will be found."

And Bruce W. Gonser adds: "The number of 'pin holes' present is influenced, not only by the effectiveness in the fluxing and the preparation of the plate, but in the thinness of the coating. Although corro-

Lead coated corrugated steel sheets on this foundry in Omaha have proved to be highly resistant to corrosion. Of course air pollution by industries is probably not severe there.

sion tests are by no means complete, those of us who have worked with lead coated steels feel that there is quite a difference in behavior between lead coated panels of, say, 0.0007 in. and those of under 0.0005 in. The thinly coated material is still excellent as a base for paint, but tends to be too thin for long exposure in weathering.

"Means are being developed for at least temporarily eliminating the tendency to rust at 'pin holes' on relatively short exposure to the atmosphere. There seems to be a tendency for the holes to heal, or at least get no worse, under continued exposure, as indicated by lead coated steel panels which have shown no more, or probably less, rust after many years exposure than after only a few months or a year."

Burns and Schuh in the book, "Protective Coatings for Metals" (Reinhold Publishing Corp.) state: "Lead film differs from that on copper, zinc and iron in that it becomes impervious to the constituents of the environment and is of the so-called 'self-healing' type, of which the air formed film on aluminum, stainless steel and chromium are examples."

Comparative Tests With Lead

The thickness of lead deposits is of no mean consideration. Lead coatings 0.00025 in. thick, exposed at a 45-deg. angle on a roof in the industrial atmosphere of Detroit, showed rust spots after 3 mo. tests; panels plated 0.0005 to 0.001 in. thick remained substantially free from rust after 10½ mo. exposure under the same conditions.

Zinc coating, 0.0002 in. thick, received the same exposure and protected against rust for 7 to 8 mo. For outdoor exposures a thickness less than 0.0005 in. of lead should not be considered, states Allen G. Gray, Electroplating Div., E. I. duPont de Nemours & Co., Inc., Cleveland, and for prolonged protection of ferrous metals exposed to weather conditions thicknesses of 0.001 to 0.002 in. are recommended. Severely corrosive conditions may require 0.004 to 0.008 in. coatings. In protected indoor exposures where 0.0001 to 0.0002 in. cadmium or zinc were formerly used, it is probable that 0.0002 to 0.0003 in. of lead would prove adequate. Lead plated nuts and bolts usually have thicknesses of 0.0005 to 0.001 in.

The exact thickness required to give an impermeable coating will depend upon the smoothness and cleanness of the initial surface and the structure of the lead deposit. "In lead coating steel in general, the metal must be cleaned much more thoroughly than is necessary in galvanizing although the same technique may be used for most articles," states A. J. Phillips.

Slight changes of opinion on thicknesses occur as experimenters gain more experience. Early in their investigations researchers of the National Lead Co. had concluded that the standard minimum thickness should be 0.0004 in. for atmospheric uses and this

Sheets, wires and crudely coiled wires are here lead coated. Despite the bending of the wire the covering has not flaked off.

has been verified by actual experience though coatings 0.0001 in. thick have proved successful when given special chemical treatment. Several consumers use this thickness of 0.0001 in. on several items where only three months' service is needed. National Lead emphasizes that lead alloy coatings for steel are for atmospheric uses only. Someday coatings for chemical and similar uses may be developed.

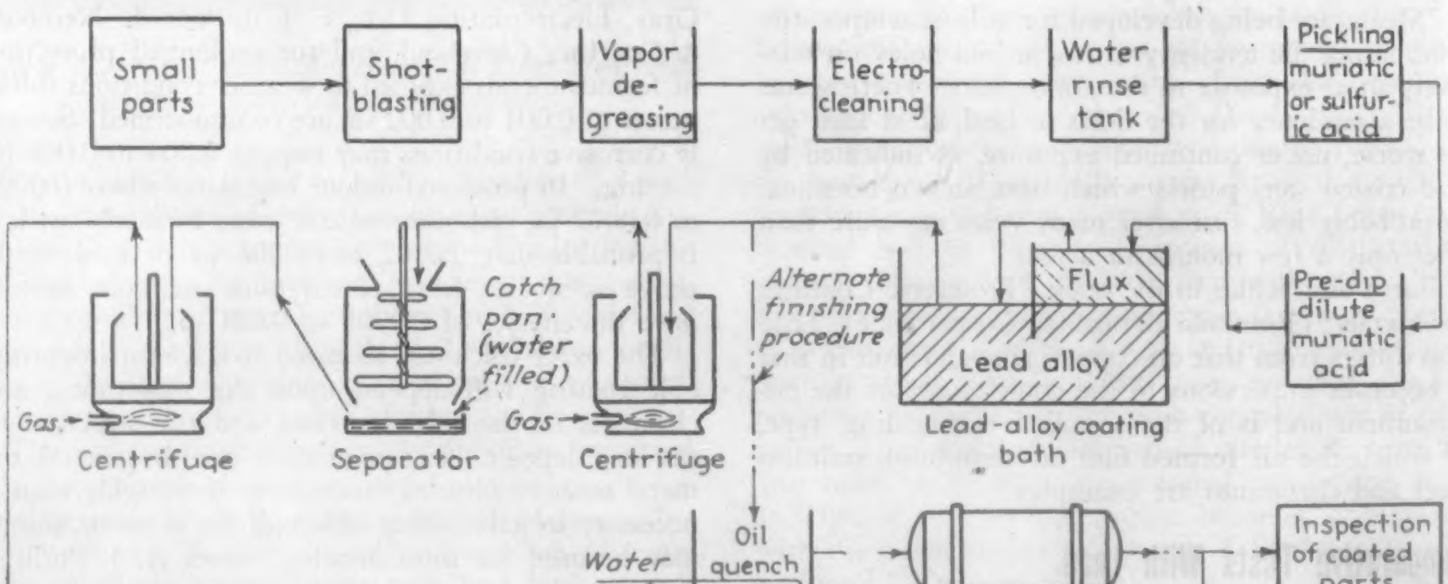
Fabrication Factors

Shall we consider how lead-coated steel lends itself to fabrication? An official of Master Metalcoaters, 2415 S. Prairie Ave., Chicago, states: "Appearance is bright to a semilustre, hardly distinguishable from a cadmium or zinc plated finish. The coating of thread bolts makes a particularly attractive job. Ease of soldering without acid flux makes lead alloy coatings desirable for electrical and radio parts.

"Many fabricated parts which are spot welded, riveted, or hand soldered can be coated and soldered at the same time, by simply tacking here and there, and then coating with lead alloy. The weight of lead coating is considerably less than zinc (due to thinner coat), thus lightening the burden of carrying equipment on the back of soldiers and sailors."

It has been found that while a lead-coated steel sheet can be easily spot welded to plain steel, it cannot be spot welded to another lead-coated sheet, states C. E. Heussner, Chrysler Engineering Laboratories, Detroit. "One can solder to lead-coated steel, but only with some difficulty."

States Gustaf Soderberg, technical director, Udylite Corp., Detroit: "Under no circumstances should lead-plated steel come in contact with aluminum.



Flow sheet of hot dip lead alloy coating of small parts. (Courtesy: National Lead Co. Research Laboratories)

Weirton Steel Co. features a lead-coated steel that can be deep drawn and formed into bends such as this elbow for a house downspout.

Generally speaking, it should also be kept away from contact with zinc and zinc-plated parts, though one may expect that a small lead-plated part would not do very great damage to a large zinc-plated part.

"Lead-plated steel ordinarily would not cause acceleration of the corrosion of copper, iron, nickel or tin. These metals are protected in seacoast atmospheres and in rural and desert atmospheres. In industrial atmospheres the lead may act either way, but in no case is the acceleration of the corrosion of either the lead or the four metals very pronounced. Hence, lead-coated parts could probably be used in contact with these metals with impunity."

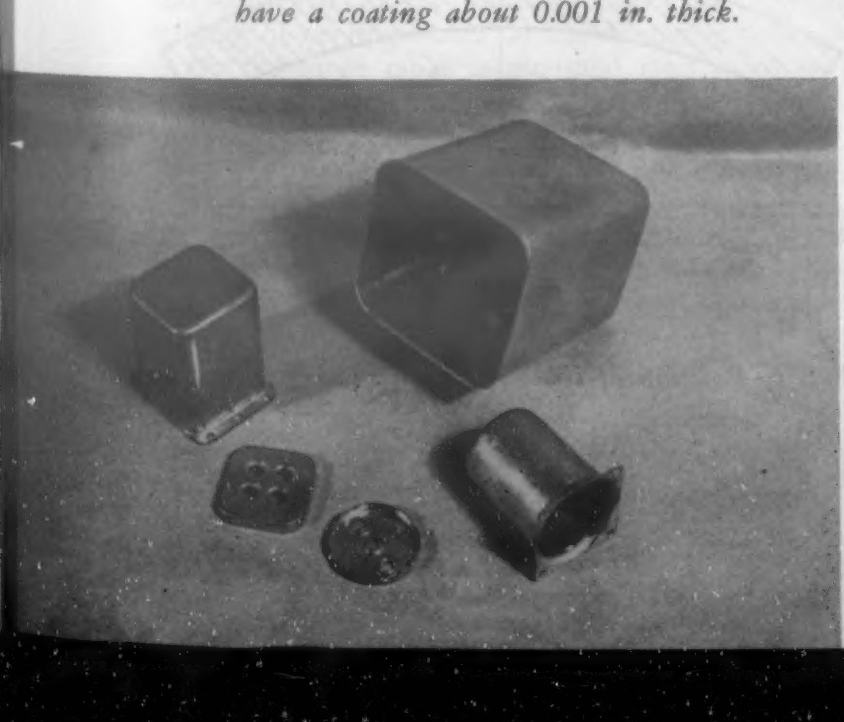
As to processing of the steel base with lead or lead alloy coating, lack of space prevents a full exposition. An accompanying diagram of the National Lead Co. portrays a typical routine.

States John D. Gold, assistant vice president, Weirton Steel Co.: "The process of coating sheets varies, depending on whether a galvanizing pot or a long terne pot is used. Heavier coatings are applied by the galvanizing pot method. Coatings of over ½ oz. per sq. ft. are readily applied in using a converted galvanizing pot—and the coating is relatively smooth.

"When using the long terne pot an oil finish is given to the sheet, and lighter coatings can be applied. These coatings are very smooth and uniform. Coatings of about 0.2 oz. can be applied using this process. The pot is operated at about 35 F. over the normal temperature of terne metal. In both cases a good acid pickling precedes the coating.

One of the main features of the National Lead process is an anhydrous flux, called "DW." This is supplied in various types to operate over different temperature ranges, the most commonly used having

Here transformer radio cans of lead alloy coated steel have a coating about 0.001 in. thick.



a melting point of 415 F. It is made and sold by National Lead. It floats readily on the surface of the lead, or alloy, bath; it is non-volatile and does not decompose upon continued heating. It can be used almost indefinitely, does not become viscous with continued use and is easily removed from the article to be coated.

Electroplating

Lead can be deposited from a great variety of solutions including the acidified solutions of acetate, fluoborate, fluosilicate, nitrate, perchlorate and alkaline plumbates. In commercial practice only fluoborate, fluosilicate and perchlorate have been used, the last more extensively in Europe.

Electrodeposition of lead can be most successfully accomplished when plated from a lead fluoborate solution, states John F. Beall, Harshaw Chemical Co. The bath is prepared by reaction of hydrofluoric acid and boric acid to form a complex compound, usually called fluoboric acid, HBF_4. When basic lead carbonate is dissolved in it, there results lead fluoborate, $Pb\ (BF_4)_2$. This is filtered and stabilized by excess of fluoboric acid and boric acid, the excess increasing conductivity and producing finer deposits.

Lead fluoborate is preferred to fluosilicate solutions because: Steel can be plated directly, while the silicate needs a preliminary copper coating; fluoborate solutions are more stable; deposits are finer. A fluoborate lead solution concentrate has been perfected that requires only dilution with water and addition of a little bone glue. The solution is 66 deg. Baume equivalent to 67 oz. of lead per gal. Operating ranges are from 13-32 oz. of lead per gal. For the same thickness of deposit it plates three times faster than nickel, has excellent throwing power, the bath operating with 100% cathode efficiency. Over 100 installations are now in operation, nearly all in war work, doing everything from bolts and nuts in barrels to large pieces in huge tanks.

The present duPont plating method dates from 1938 and depends on commercial scale manufacture of sulfamic acid, a chemical that for 66 yr. had been a laboratory curiosity. The plating system consists primarily of an aqueous solution of lead sulfamate, with sufficient free sulfamic acid to make a solution having a pH of about 1.5 and containing selected addition agents.

The Republic Steel Corp., Cleveland, is one of the latest companies to go into lead-coated sheet manufacture, at least experimentally, using the electroplating process. They are encouraging customers to test their product for uses for which they consider it satisfactory.

Undoubtedly the end of the two wars will see more data released on the general subject of lead coating. We are told by a Battelle Memorial Institute man: "Unfortunately the investigation work, both on electroplating and hot dipped coating, has been solely for the War Metallurgy Committee and all reports have been 'Restricted.' "

Quoting John F. Beall once more, for a concluding thought: "It is widely felt that lead plating will achieve an important position among metal finishes when peace time is again restored."

Continuous Annealing of Cartridge Cases

by CLARENCE A. MAURER *General Manager, The Drever Co., Philadelphia*

A METHODS ARTICLE

Typical of the engineering ingenuity that has been characteristic of America's war production effort is this smart adaptation of a continuous convection type tempering furnace to the continuous annealing of brass cartridge cases. The furnace design and operating details and the results obtained are described.

—The Editors

When an Eastern manufacturer of brass cartridge cases was requested by the Ordnance Department to double his production, an additional furnace to anneal the cases between draws was required. Personnel of the furnace section, salvage department of the Philadelphia Ordnance Division, assumed the responsibility of obtaining a suitable furnace from the list of canceled equipment in their district.

A complete canvass was made and a contract awarded the Drever Co. of Philadelphia, to dismantle a Drever roller hearth convection-type furnace originally designed for continuous tempering of armor plate, change it to use existing handling equipment, and erect it at the cartridge case manufacturer's plant, ready for production.

Furnace Design and Operation

The only design change in the furnace proper involved the method of guiding existing baskets which are used to convey the cartridge cases through the furnace. These baskets were designed for use with the original furnace in the manufacturer's production set-up and were fabricated from alloy rod at a high cost. Alloy collars welded to the alloy rolls engage on the outside of the guide rods extending below the bottom of the basket and permit the weight of the loaded basket to be carried on the "runners" extending the full length of the basket on tne bottom between the guide rod and outside edge of the basket. This is illustrated in Fig. 1.

The addition of the collars on the rolls necessitated a change in the wall and steel shell construction on one side to allow for insertion of rolls. Some slight changes were made in the wall thickness and in the height of the throat arch to permit the loading of two baskets across the width of heating chamber.

Of the material used in the construction of the furnace, approximately 40% of the dollar value was obtained from various canceled orders originally issued under United States Government contracts. The charge and discharge tables only had to be designed and built new to fit in with the established production flow line.

In operation, the baskets are automatically loaded at the draw press, moved to the charge end of the furnace on a gravity roll conveyor and loaded on the charge table rolls by means of a traveling overhead hoist (Fig. 2). The baskets pass through the furnace, are heated to the annealing temperature and discharged, this sequence being automatic and continuous. To permit handling in a minimum time after discharge from the furnace, a spray quench, 6 ft. long, equipped with hand-operated water spray manifold on top only, is built over the discharge table approximately 2 ft. from the furnace. (Fig. 3.)

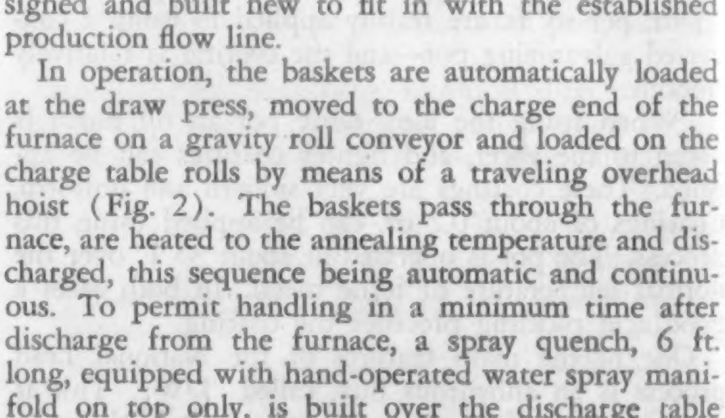


Fig. 1. Position of the baskets on the furnace roller.

Fig. 2. Charging end of the recirculating type roller hearth furnace for annealing brass cartridge cases.

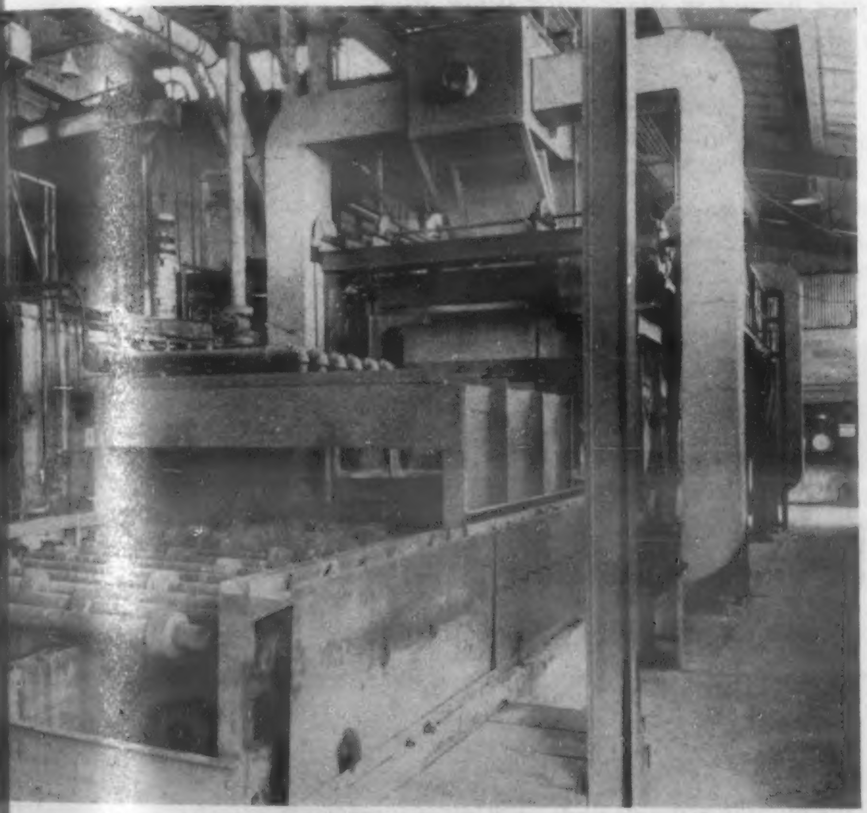


Fig. 3. Discharge end showing quench of the same furnace in Fig. 2.

Emerging from this spray hood, the cooled baskets are individually lifted from the table by a traveling overhead hoist, tilted to drain off any remaining water and conveyed to the pickling tanks. To prevent spillage of cooling water on the operating floor, the entire discharge table is mounted over a properly drained concrete pit, whose sides extend 15 in. above the floor level.

The furnace is designed to heat 7500 lb. of brass cases and alloy baskets per hour but normal operating practice as established from the start, produces 9500 lb. and, when production demands, as much as 11500 lb. per hr. are discharged from the furnace, with no rejections from improper annealing.

The two-zone recirculating type furnace is designed for operation between 300 and 1200 F., and has a heating chamber 40 ft. long by 6 ft. 10 in. wide by 15 in. high at the spring of the furnace arch. Two city gas-fired recirculating air heaters with individual combustion chambers and alloy fans for handling large volumes of air at a maximum temperature of 1375 F. are mounted on a fabricated steel structure above the furnace and independent of the steel furnace shell.

Auxiliary Equipment

Annealing temperatures in each zone are controlled by an indicating, recording, air-operated, potentiometer controller, each effecting control by automatic regulation of an air-actuated diaphragm, V-port, reverse-acting valve which controls combustion air flow to the burners of the heaters. A 4-point potentiometer recorder is also provided to check the temperature at each control point plus two extra points to record temperatures in the heating chamber or recirculating system under operating conditions.

Each air-heater is also equipped with a millivoltmeter type indicating controller to protect the circulating fan. The thermocouple for this instrument is located in the discharge duct of the air-heater combustion chamber and should the temperature at this point reach the control setting on this instrument, the fuel supply is automatically shut off until the temperature drops below the control point when the furnace temperature control instrument picks up the control of fuel to the burners. All pyrometric instruments are mounted on a panel at the charge end of the furnace in full view of the furnace operator.

The gas burners on the air-heaters are protected against flame failure by a device that uses the flame to complete an electrical circuit. Included in this circuit are solenoid valves located in the gas lines to the main and pilot burners. Only when flame is established on the pilot burner is this circuit energized and the solenoid valves open, permitting gas to flow to the burners. A safety valve is installed in the main gas line to shut off fuel to all burners in case of a pressure drop in the gas supply or a power failure to the combustion blower.

The two flame protection instruments and push buttons to start and stop the ignition system, circulating fan motors, combustion air blower and drive motor are mounted on an operating panel located by the pyrometric instrument panel. Also mounted on this panel is a tachometer indicating conveyor speed and a push button control to regulate drive speed.

The rolls on the charge and discharge tables consist of standard 2½-in. pipe with adjustable cast iron collars to guide the baskets. The furnace rolls are 3½ in. diam., hollow, of 25/12 alloy, each with four collars 6½ in. o.d. by 3 in. wide welded to the rolls, properly spaced to guide two rows of baskets through the furnace is located a hand operated clutch to disone variable speed drive providing a roll speed variation between 2 and 12 in. per min. At each end of the furnace a hand operated clutch disengages either table from the furnace proper should occasion demand it. All rolls are spaced on 9-in. centers and equipped with self-aligning anti-friction bearings.

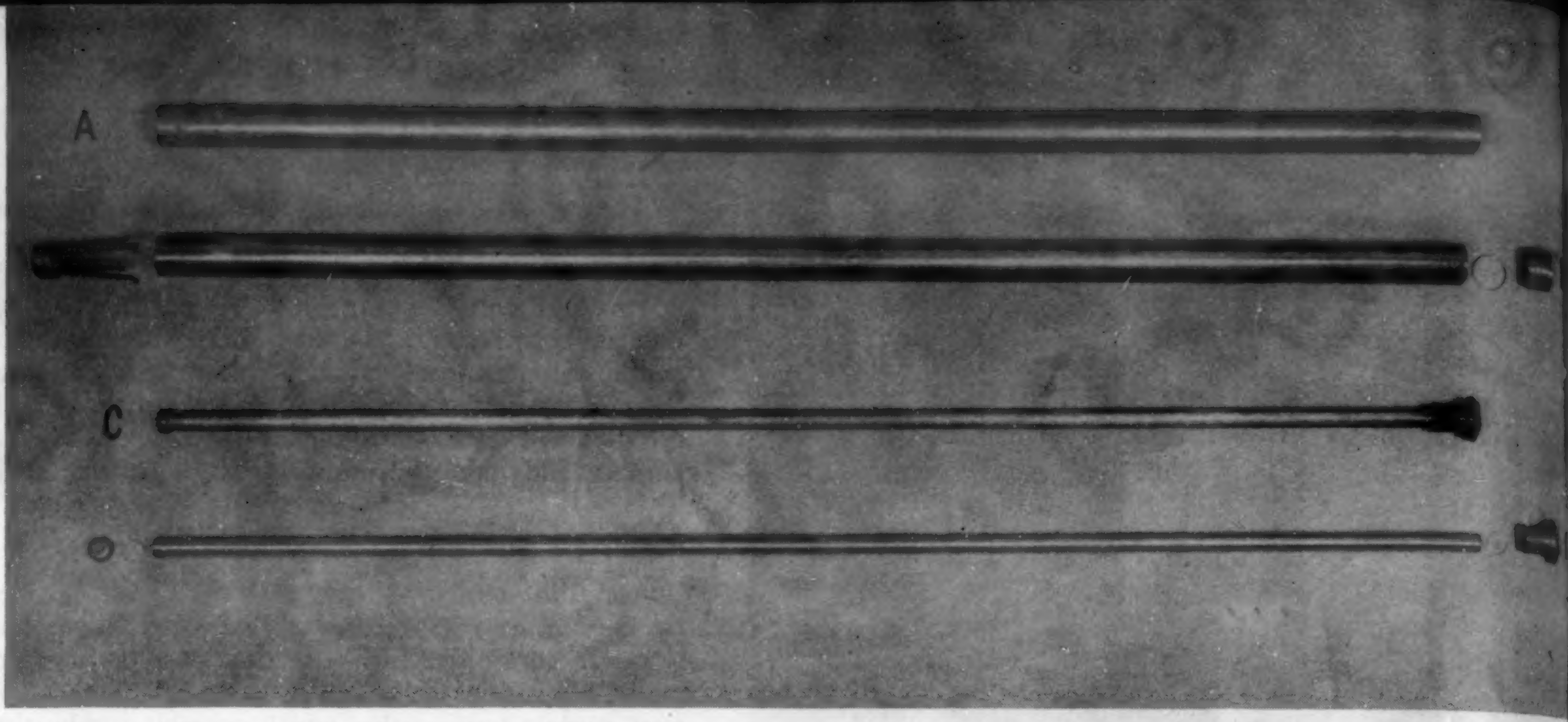


Fig. 1.
(A) The outer tube or white phosphorus container with aligner cap and collar brazed in place with silver alloy (Easy-Flo). The tube is 37 in. long and 1 in. i.d.
(B) Outer tube assembly. Left: Silver alloy ring made of 1/16 in. wire, 1 in. i.d. and aligning cap into which inner tube fits. Right: Collar and 3.64 in. wire ring of silver alloy, 1 in. i.d.
(C) Burster charge well assembly with cap and adapter brazed in place with silver alloy.
(D) Inner tube assembly. Left: Cap and silver alloy ring, 1/32 in. wire, 9/16 in. i.d. Right: Adapter and brazing alloy ring.

Induction Brazing of Bomb Burster Units

FOURTH IN A SERIES OF ARTICLES ON INDUCTION HEATING

by COL. HARRY R. LEBKICHER *Commanding Officer, Chicago Chemical Warfare Procurement District*

CHEMICAL WARFARE is one of the most notable services in the American armed forces. It has been a key division of the Army ever since the Germans first opened up with a gas attack in World War I. But perhaps because of its spectacular outburst "chemical warfare" has always been associated with "gas." Consequently, the public has not known of the really wide scope of the CWS.

Even before we were ambushed into the war, chemical warfare had gone far beyond gas. It had covered the development of many types of munitions, it had controlled their procurement, it had supervised the training of troops in their use, and today it covers actual combat on the firing line. These munitions include the 100 lb. chemical bomb with the M-13 burster unit (the latter described in detail in this article), the 4.2 mortar, the 4.2 shell, the M-15 hand grenade, the M-54 thermite incendiary bomb, the gas mask and the flame thrower.

With the advent of war, speed of manufacture became equal in importance to perfection of output. Both of these factors were achieved through the close and intimate cooperation between CWS and industrial engineers and metallurgists, among the foremost those who specialized in low temperature silver brazing.

In the manufacture of Chemical Warfare products, joints must be sturdy, to stand the extraordinarily severe service in the field. At the same time they must be so designed as to make fabrication and assembly simple and practicable from a manufacturing standpoint. Also, parts must be removable and replaceable to facilitate quick repairs in the field made necessary by damage in action.

Obviously, all types of assembly methods are used: unit casting, assembly by welding, brazing and soldering. The most practical for many purposes has proved to be brazing with low temperature silver-brazing alloys. It provides tight joints, free from

leakage, and with strength equal to the solid materials joined.

The vital need for silver in this form is made abundantly clear by the huge quantities used. For example, the burster unit for the 100 lb. bomb has four silver brazed parts and the total consumption will be well over 100,000 ounces of the silver alloy for one order of 1,600,000 bombs. Even before Pearl Harbor, the Chemical Warfare Service was using large quantities of silver brazing alloy. As an instance, they were making 20,000,000 incendiary bombs, using for that purpose between 4,000,000 and 5,000,000 ounces of a low temperature silver brazing alloy known as Easy-Flo.

A METHODS ARTICLE

This pictorial article presents the operating steps in the silver-alloy-brazing of one of the many chemical warfare service products now being fabricated by this modern method.
—The Editors

Silver Alloys Used for Brazing

The Chemical Warfare Service has fully recognized the technical importance of this phase of their work by setting up rigid specifications for silver brazing alloys, as shown in the table.

Table of Specifications and Characteristics of Silver Brazing Alloys

U. S. Army Chem. Warfare Service Spec. 196-13-80	Silver Content of Alloys, Per Cent	Flow Points Degrees F.
3	15	1300
4	50	1175
5	50	1270
0	20	1500
1	45	1370
2	65	1325

Fig. 2. Inner and outer tubes arrive at the brazing station cut to size and are loaded onto alternate racks in the conveyor, which takes them to another floor and the cleaning machine shown here. Here the unbrazed tubes are degreased in trichloroethylene at a temperature of 160 F. Every other rack has been loaded with tubes which have already been brazed. Brazed and unbrazed tubes go through this cleaning process together, which is in effect the first and last stage of the process.

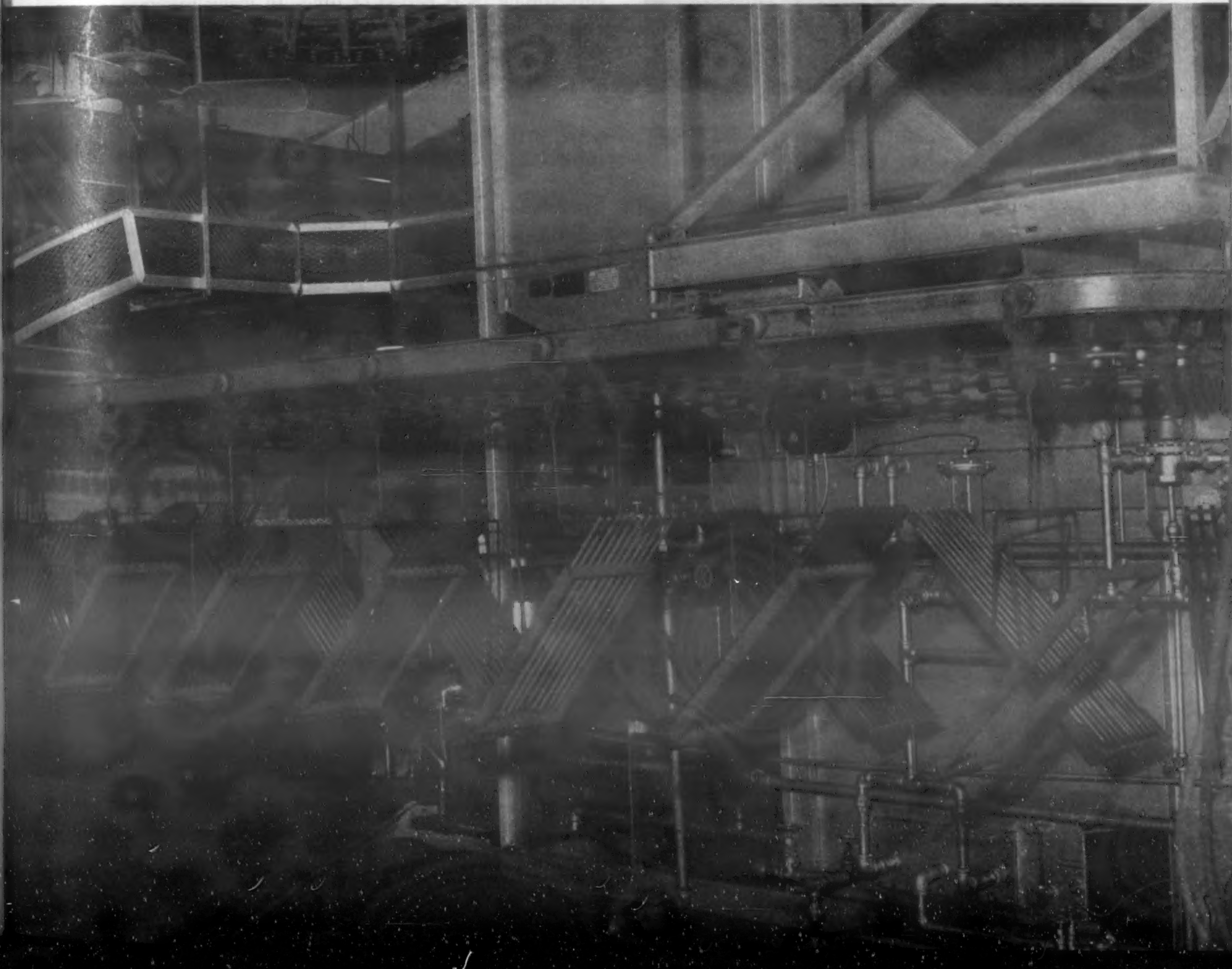


Fig. 3. After aligner caps are inserted in the large tubes, the brazing surface inside the collar end of the large tube is brushed over with the flux (Handy-Flux).

Fig. 4. Rings of 1/16 in. brazing alloy wire, 1 in. i.d. are inserted in the collar end of each tube.

An Ordnance Dept. Tentative Specification (No. AXS-500) is applied to silver-brazing fluxes that must be fluid from 1100 to 1600 F.

The low temperature silver brazing alloy used in the operations described in this article is known as "Easy-Flo" and the flux used is called "Handy Flux"—both made by Handy & Harman, New York.

The chief components of the standard silver-brazing alloys are silver, copper, zinc, nickel, cadmium and phosphorus. Tensile strengths of these alloys in themselves range from 40,000 to 60,000 p.s.i. and when thin films are used to join metals they have the unique ability to give joint strengths far above their original strength, usually equal to the strengths of the metals joined. Ductility ranges from about 5% to over 35% in 2 inches; electrical conductivity in a properly made joint equals that of copper, and color varies from yellow to white. A joint of almost any physical properties within these limits can be obtained by using the correct silver-brazing alloy.

Perfect cleanliness of the joint surfaces and good fluxing are of utmost importance in silver alloy brazing. Flux dissolves any oxide that may form on the surface of the metal while pre-heating protects the heated surface from atmospheric oxidation, and facilitates easy "tinning" by reducing the surface tension which aids the flow of the alloy.

Contrary to the ideas of many unfamiliar with this metal joining method, silver-alloy brazing is not difficult. Any operator who has mastered fusion welding and bronze-welding or who knows how to handle soft solder can manage it easily. Operators with no metal joining experience at all can be trained in a surprisingly short period of time. In many instances (as in the set up described herein) the heat for brazing may be supplied with virtually fool-proof control by induction heating methods.

A step-by-step descriptive and photographic study of the induction brazing of the M-13 burster tube assembly for the CWS special 100 lb. incendiary bomb, using silver brazing alloys may help to demonstrate for both design and production engineers the possibilities in this modern fabricating method.

The CWS special 100 lb. bomb is used by the Air Forces in raids to soften enemy strongholds and to support attacks by land and sea. It is a "thin case" steel bomb, designed to use a light burster charge and an instantaneous point detonating fuse.

The bomb is loaded with incendiary filling. It has been used against oil refineries, oil dumps and ammunition dumps for starting fires to wipe out enemy supplies. Bombs of this type were used against the Rumanian oil fields in the Ploesti raid, as well as in attack on bridges, troop columns on open roads, troops in a defile, or in an assembly area.

The adapter in the nose of this bomb is brazed to the body with a silver alloy and joined to this adapter is the M-13 burster unit which has four parts brazed with silver alloy.

The Burster Tube Assembly

The M-13 burster tube assembly is being turned out by Electromaster, Inc., Detroit, Mich., among other plants. The tubes which make up the assembly are cut to size elsewhere, and sent to Electromaster

Fig. 5. Flux is brushed on the collars by the girl on the right. The operator then takes a collar from the table and places it in the far end of a jig fastened to the bed of an air operated press. The other end of the tube has already had an aligning cap inserted. The tube is clamped in place and the air pressure turned on—collar and cap are settled in place in one operation.

Fig. 6. The large tubes are then placed in an induction heating unit (an Induction Heating Corp. machine) with the collar end down. The brazing alloy has previously been preplaced inside the tube. While the 8 tubes at the left are heating the operator loads the 8 stations at the right. Heating time for brazing 8 tubes is 35 sec. Note heat marks on tubes being heated at the left and how close they are to the joints.

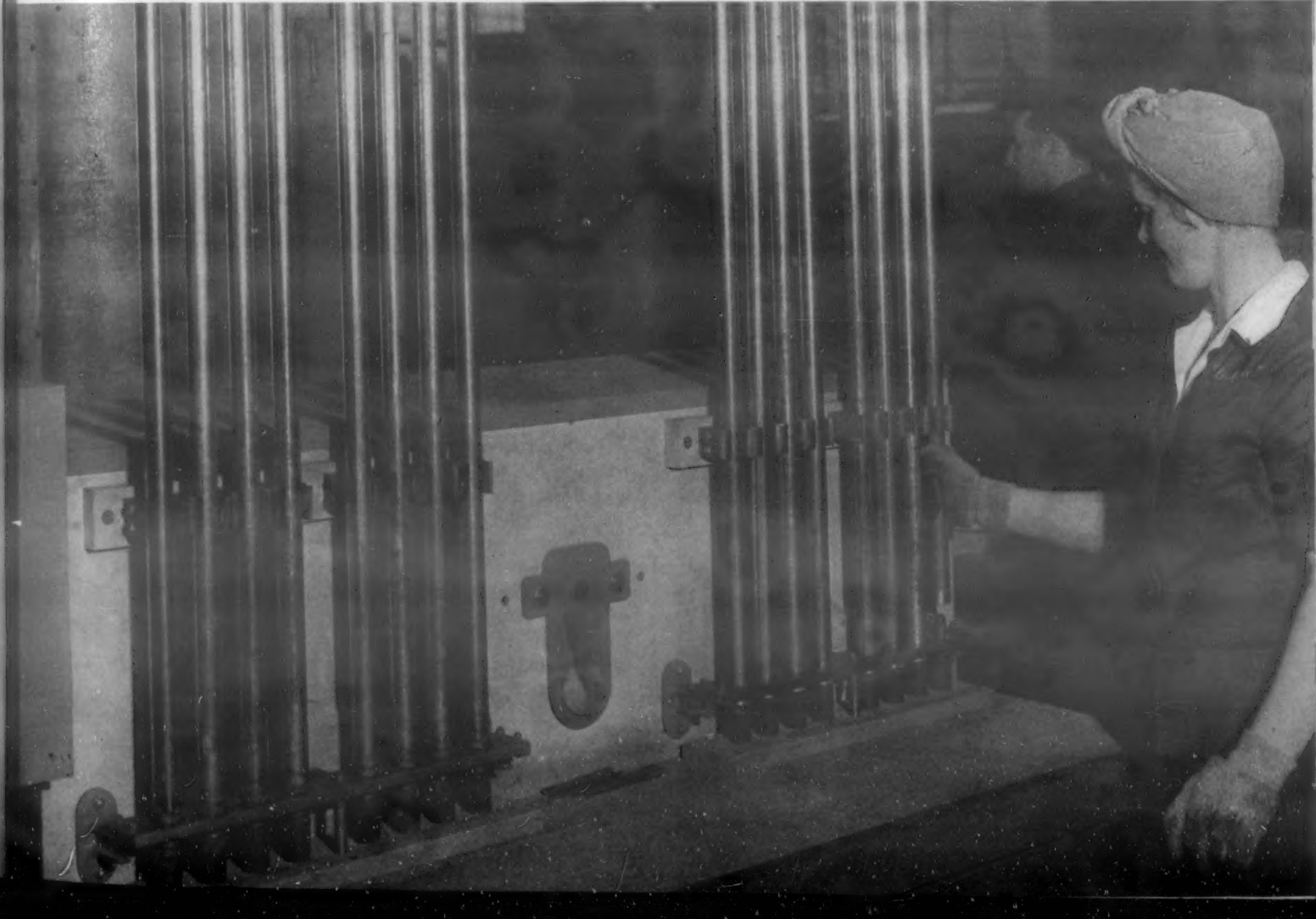


Fig. 7. Fluxing the outside of the aligning cap and the edge of the tube. Fluxing is done after assembling the cap in the tube to prevent excess being left inside. As the joint is heated and the flux becomes liquid just the right amount sinks into the joint to assure the clean surfaces required.

Fig. 8. In joining the aligning cap to the large tube, 8 units are brazed at a time—while one set is heating and is loaded into another set of 8 coils and a ring of 1/16 in. brazing alloy wire 1 in. i.d. is placed on top of the joint. Heating time for 8 units is 28 sec. The heat is turned on by a lever in the center of the machine, and is automatically timed and turned off.

to be assembled and made ready to be filled with their charge. There are two tubes: one, 37 in. x 1 in. i.d. (the white phosphorus container) and one, 36 in. x ½ in. i.d. (the burster charge well assembly). The tubes are brought to the brazing department by a conveyor from a degreaser, which removes all grease, oil, etc.

The larger tube (the white phosphorus container) is capped at one end with an aligner assembly; at the other end an adapter consisting of a collar with inside thread, is attached. The smaller tube (the burster charge well assembly) is capped at one end, and at the other end, an adapter consisting of a hollow plug, outside threaded at one end and with hex head at the other end, is fitted over the end of the tube.

The small tube is fitted into the large tube with the capped end of the small tube guided into the aligner assembly at the closed end of the large tube. The end with the outside thread and the hex head screws into the inside thread of the open collar. A tight fit is achieved by a soft lead washer between the hex head and a seat inside the collar.

There are 14 operations on the large tube (white phosphorus container) and 14 on the burster charge well assembly (smaller tube). The various steps are shown in the accompanying illustrations and captions.

Before the war this company manufactured electric toasters, electric ranges and stoves, electric tea kettles and hot water heaters. The conversion to war products was effected by the installation of the special conveyors, jigs and the induction heating units described above. After the war they expect to revert to their old products, using much of the new equipment, especially the induction heating units. They were familiar with silver alloy brazing before the war and expect to continue to use it, finding it much better for their purposes than welding.

Fig. 9. Burster charge well assemblies are made of smaller tubing—9/16 in. o.d.—and have a cap on one end and an adapter on the other. Before reaching the operation shown here the tubes are cleaned, removed from the conveyor and laid on tracks, and a silver alloy wire ring 9/16 in. i.d. is slipped over one end. The cap is then forced onto the end of the tube and the silver alloy ring slid into position against it. The other end—the adapter end—is next dipped in flux. Finally—as shown in this picture the fluxed tube is inserted in the adapter and is hammered against a metal bar to secure it in place.

Fig. 10. After the burster tubes have been placed in a press and the cap adapter seated in place, the cap end of the tube is painted on the outside with flux. Girls perform this operation very rapidly.

Fig. 13. For brazing the adapter ends, the burster tubes are inserted in another Induction Heating Corp. induction heater and a silver alloy ring is placed on top of the front. Eight units are heated at one time in 25 sec.

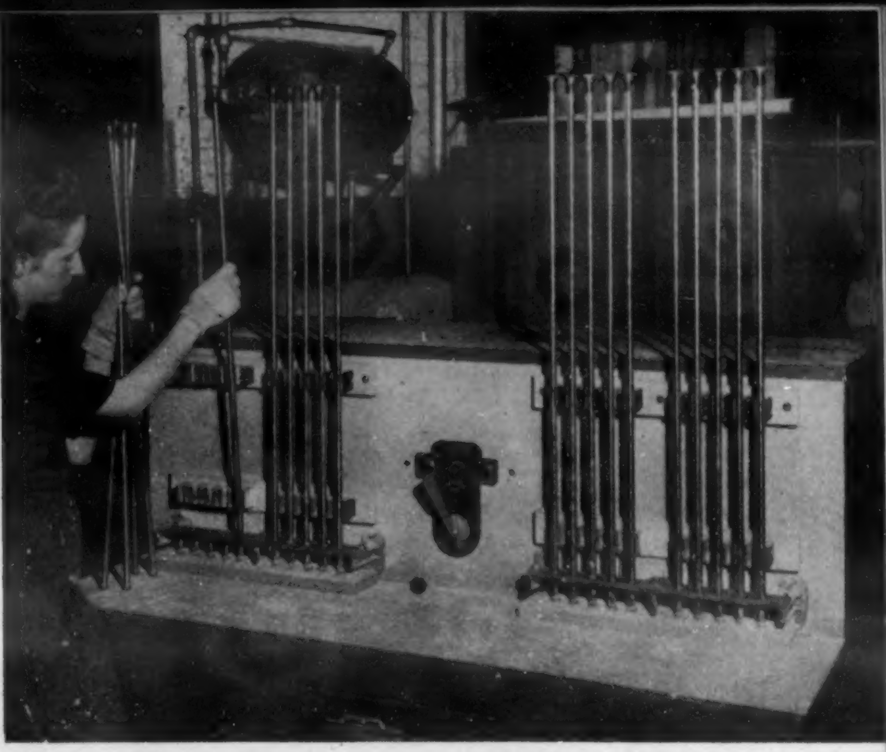


Fig. 11. The burster tubes are then inserted in induction heating machines for brazing the cap ends. Note the spring clamps—they are snapped into place for holding the tubes in brazing position. Ten units are brazed at one time on a double set up. One station is loaded while the other heats. Heating time for the 10 units is 11 sec. Heat is automatically controlled. All the operator does to start heating is push the control lever in the center toward the side to be heated.

Fig. 12. Then the outer end of the adapters into which the burster tubes have been pressed is painted with flux.

Fig. 14. The inner and outer tubes are washed in hot water to remove the brazing flux.

Fig. 15. Inner and outer tubes are tested under water at 200 lb. air pressure. About 1% are leakers and require reworking. On rare occasions when parts of maximum tolerance limits come together a cap, collar or adapter will split and be rejected. Notice the girls in the rear of the testing tanks who put the tested parts on the racks of the conveyor which takes them to the degreasing machine where they are given a final cleaning.

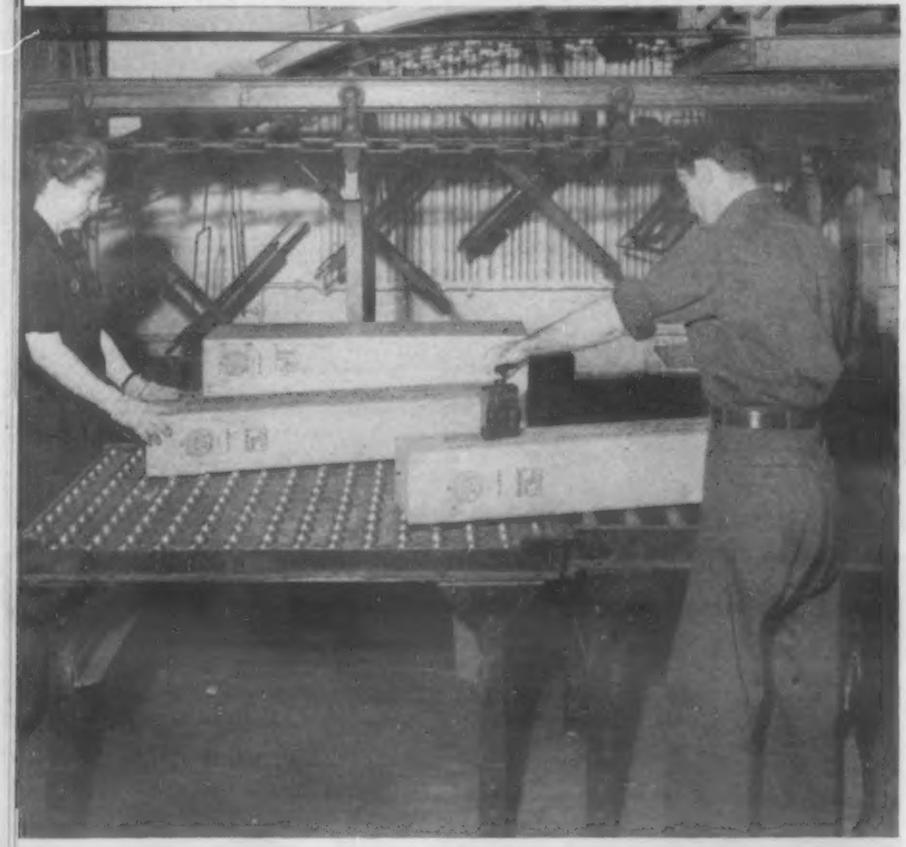


Fig. 16. The clean outer tube assemblies and burster charge well assemblies are packed in shipping containers ready for loading at another plant. Boxes after sealing and marking are slid on to a conveyor which takes them down to the railroad loading platform.

Nitriding Ferroalloys—A Correction

In the article "Nitriding Ferroalloys" by R. H. and D. Steinberg, page 630 in our September issue, the composition data given in Table I were incorrectly shown in some cases. There was actually no cobalt determined in the alloys and the percentages given as of cobalt should have been percentages of carbon.

The correct compositions are:

a. V 38.25%, Si 8%, C 0.71%
b. Zr 39.5%, Si 48.8%, Fe 11%, C 0.25%
c. Mo 61%, C 0.05%
d. W 71%, C 1.25%
e. Cb 57%, Si 6%, C 0.27%
f. Ti 40%, C 0.04%
g. C 0.83%

General view of the centrifugal steel casting department of the Oklahoma foundry.

Unique Centrifugal Steel Casting Method

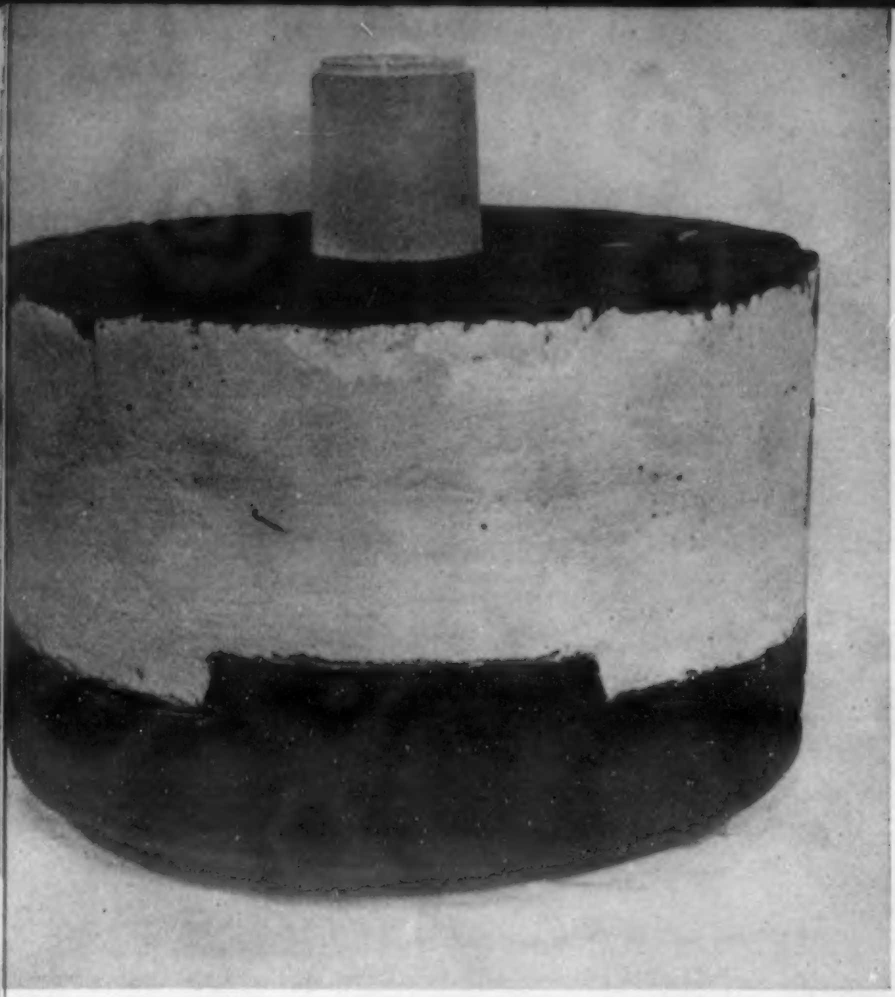
by GERALD E. STEDMAN

A METHODS ARTICLE

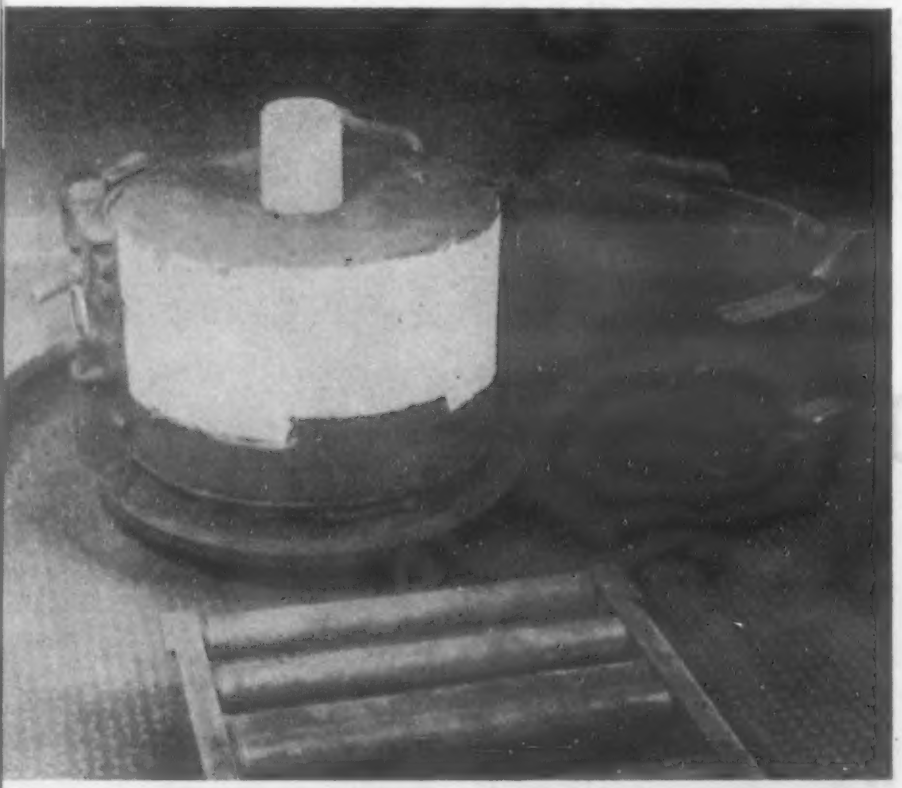
There are several alternative methods of carrying out the centrifugal casting of steel and many have been described in past issues of this magazine. But the technique for centrifugally casting steel sheaves and other parts described in this article is one of the fastest yet developed and should be of wide interest to foundry engineers concerned with achieving the highest possible production output.
—*The Editors*

"THERE IS NO INDUSTRY that makes greater demands upon steel than does the oil industry today. Deeper drilling, greater speeds, enormous loads, heavier stresses necessitate higher tensile properties from the draw-works to the bit," Burtner Fleeger, president of Oklahoma Steel Castings Co., Tulsa, Okla., remarked as I made my visit there recently.

The modernity of the Oklahoma Steel Castings plant layout, its extreme care in pattern making, melting technique and casting procedure, certainly indicate the company's deep awareness to quality casting requirements of oil field and other equipment. The company now produces thousands of different types



A closed mold for a sheave casting to be cast in a centrifugal machine.



The closed mold is transferred on rollers from the molding floor to the flask in which it is finally enclosed.

of castings, varying from a few ounces to 4000 lb. for many customers within a 600 mile radius of its large Tulsa plant. It is favorably known for its "Tuf-Wear" series of alloy steels, which now represent over 35% of the plant's output.

Better to serve its wide list of oil and railroad equipment customers, the company was one of the first foundries nationally to install a centrifugal casting department, which is now responsible for a third of its casting volume. Nathan Janco, widely known consulting engineer to American and Canadian foundries, inventor of the centrifugal casting machines used by this company, and formerly advisor to the Oklahoma Steel Casting Co., states: "The company has one of the most advanced and best equipped centrifugal casting setups in the nation." And he should know.

It was, therefore, a distinct privilege which Anton Johnson, works manager of the plant, afforded in superintending personally the observations upon which this article is based, and in permitting a description for the first time of his centrifugal casting technique. He is an expert on foundry practise, with many authoritative articles on gating and feeding to his credit.

Molding Practice

The company standardizes entirely upon vertical centrifugal casting and employs the dry sand and mold practice. It casts valves, sheaves, tubes, gear blanks, sprockets and many special shapes. About the only type of casting that is poorly adapted to the centrifugal technique is one with non-uniform or too-thin metal sections such as would require special pads, auxiliary gates, chills and blind heads of too elaborate nature for economical cleaning, according to Mr. Johnson.

The fact is that neither symmetrical nor cylindrical castings are essential to vertical centrifugal casting. Proper directional solidification can be arranged by auxiliary pads for unusual configurations and odd shapes. This article describes its production of sheaves and is representative of other products.

The patterns are mounted on 1 inch thick round plywood boards and inserted in cope and drag mold boxes. The molding practice is not essentially different from that used in static casting. Attendant photographs illustrate salient details. The dry sand method is used in line with quality control, although in some respects more expensive. This permits harder ramming and a tighter pack, which, in combination with lower speeds, tends to eliminate scabbing, cutting and erosion in the rotating action. Cores are made on Hermann jolt rollover draw machines and dried in Foundry Equipment Co. recirculating core ovens, which accommodate the internal cores as well. Type of sand varies with the job, ordinary silica oil sand being proper for most specifications. The company uses Arkansas and Evansville types of these.

The method of closing the cope on the drag varies, relative to size. Smaller matings are manually closed, using side hand holes. Larger matings are hoisted mechanically. Match-up of cope and drag is either by offset joint on the mold's outer edge, or preferably by round tapered guide cores when the job permits. The cope and drag halves are held together by a cover which is placed over the cope top and clamped by an arm fastened to the flask side of the centrifugal machine which is swung into position over the cover. The fit is tightened by two tapered surfaces conjoining, on the order of a cam, which forces the arms down on the cover. This cover has a center hole to accommodate the location of the runner cup.

A guard for the machine consists of a cover that fits over it, being raised and lowered by hoist on the monorail, directly over the center of the machine and into the runner cup. From the electric melting furnaces at the far end of the foundry, the metal moves to the centrifuging zone by transverse ladle on overhead crane, and from there into pouring ladles that are kept coasting between pours by natural gas torch. The rate of pour runs between 3 and 5 lb. per second, the machine being in centrifugal rotation.

The Centrifugal Machines Used

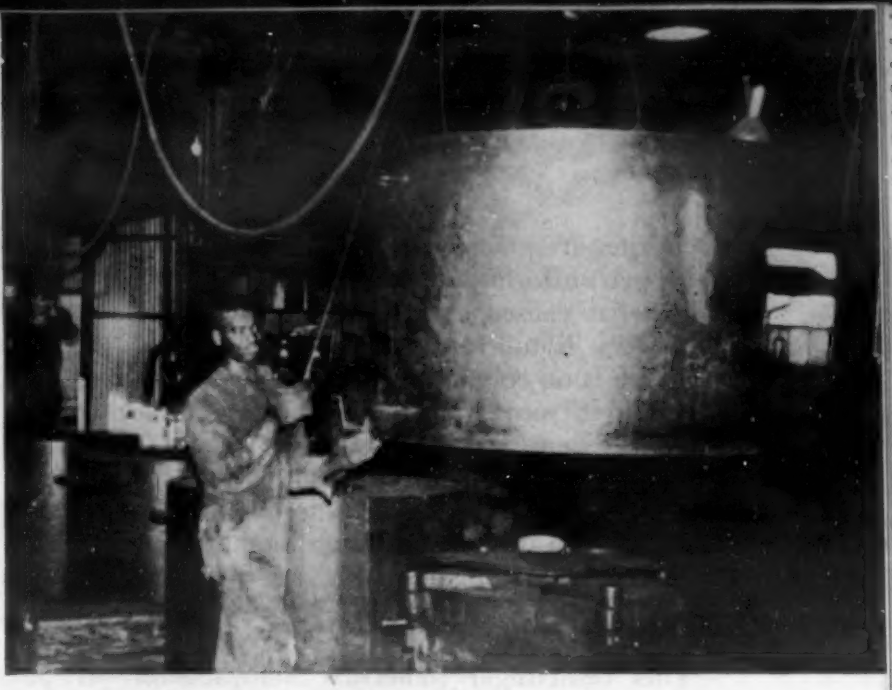
The company maintains three 34-in. diam. and three 25-in. diam. vertical centrifugal casting machines, facilitating molds up to 30 in. in height, made by The Centrifugal Casting Machine Co. of Tulsa. These are rapid feed, vibrationless, variable speed machines with precise control and with sturdy safety features. These machines have an extraordinary electrical driving unit which has complete rheostat speed control from zero to 1700 r.p.m. Power is provided by a concentric two-shaft motor; the first shaft being a squirrel-cage-wound armature, the second an eddy current clutch. Another eddy current is used as a clutch brake. This latter controls the excitation to the clutch which controls the current "talk" to the machine, establishing the infinite speed control. The controller is rheostatic and mounted on a control panel which also carries a tachometer to read machine speed as well as an ammeter, pilot light, push button starter and run-coast brake switch.

The machine itself is serviced by a roller conveyor, discharging onto a roller table of the machine inside a flask body, accommodated by quick acting clamps, that houses the mold which is properly covered and clamped as described and encased in a guard. Sturdily built to be vibrationless, even when necessary to spin castings that are not symmetrically arranged about the axis of centrifuge, these machines have many safety features. The spinning action creates hazards of metal spraying from the runner cup or molds flying off the table, against all of which the machines are completely fortified.

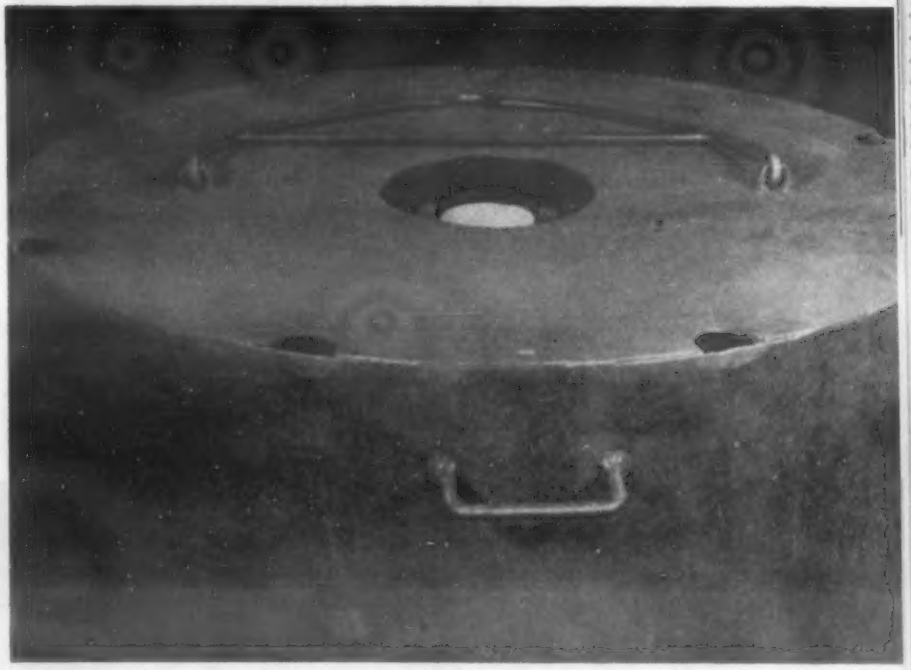
Clocked with a stopwatch, the centrifugal casting practice indicated an elapsed time of 90 sec. on the 34-in. and 40 sec. on the 25-in. between spinning stop, unload and recharging with fresh mold; the actual time between guard on-off-on. This is fast work; the average time elsewhere is around 210 sec., and in some instances, as high as 10 min. This speed naturally contributes to greater yield.

Returning to the casting of the sheaves, having been loaded, centrifugally poured, and unloaded from the flasks by roller conveyor, they are sent to the cooling room and then to the Simplicity shakeout machine and are removed from it by overhead monorail hoist. The core lumps drop from the end of the shake out table, actuated by eccentric, into a hammer mill and then on to two vibrating screens, one 3/16-in. and the second of 20 mesh. The sand is then conveyed to the washer, cleaned and returned to reclaimed sand storage.

"Steel can be poured colder by centrifugal casting than in the static practice," Mr. Johnson emphasized. "Centrifuging also prevents cold shuts or wrinkles, adding greatly to appearance, which is pleasing to the customer. Centrifuging during the pour causes the metal to flow immediately to the outside of the mold cavity. This first metal in the mold will chill first; the last entering metal will be in the center of mold and gate, establishing proper directional solidification which is, of course, as important in producing centrifugal castings as in static practice."



The closed flask containing the mold is clamped down and the guard is ready to be lowered.



The flask containing the mold enclosed in the guard and ready for pouring.

Some Advantages

Though generally understood, the advantages of centrifugal casting, because of this directional solidification, merit brief restatement. In static practice, the casting cools from inside and outside surfaces simultaneously toward the midsection, wherein impurities are trapped, and dendrites forming from both surfaces, meet at the center; tending to leave a weak, "amorphous" structure. The centrifuging action, on the other hand, forces all impurities to the center where they are easily eliminated or thoroughly machined away. The dirty, unsound midsection is avoided.

Trapped flaws are not hidden within the casting to be discovered only after much useless machining has uncovered them in the further fabricating process.

Dendrites are practically eliminated by the centrifugal force. A uniformly dense, fine grain structure results which has caused the process to be called by some engineers "liquid forging."

There is no columnar growth. The resultant tensile strength in some steels is improved because of the increased density and consequent homogeneity. Dimensions are more uniform. The centrifugal casting has equal strength in all directions. There is a tendency towards greater peripheral density which makes the centrifugal casting method preferred for gears, sprockets and pinions whose bearing surfaces receive wear.

This centrifugal molecular compression on peripheral surfaces, together with the purifying action, produces in effect a tougher case. Rather than to be parallel to the lines of force, which is a characteristic of the flow lines of the conventional gear casting, there are no shrinks or flow lines in centrifuged castings and the grain structure runs perpendicularly to the gear tooth line of force, an advantage in precision machining.

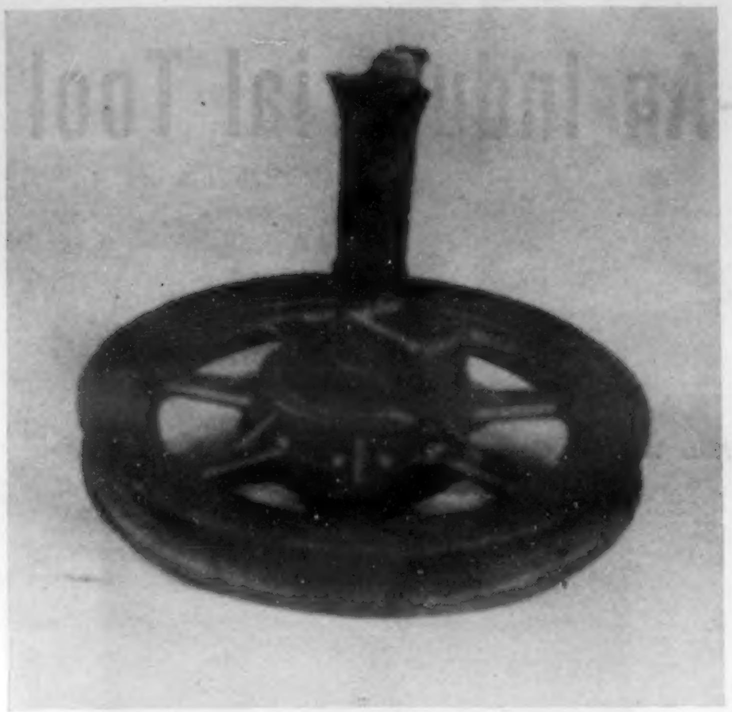
"It is essential closely to analyze each job before attempting to cast it to be sure it can be produced satisfactorily," Mr. Johnson pointed out. "In this observed case of sheaves, there are various types . . . spoke, solid web, and web with holes. The spoke type, with light metal sections in the spoke area and heavier metal around the groove, necessitates increasing the spoke metal section which can usually be accomplished by increasing the radius. The web

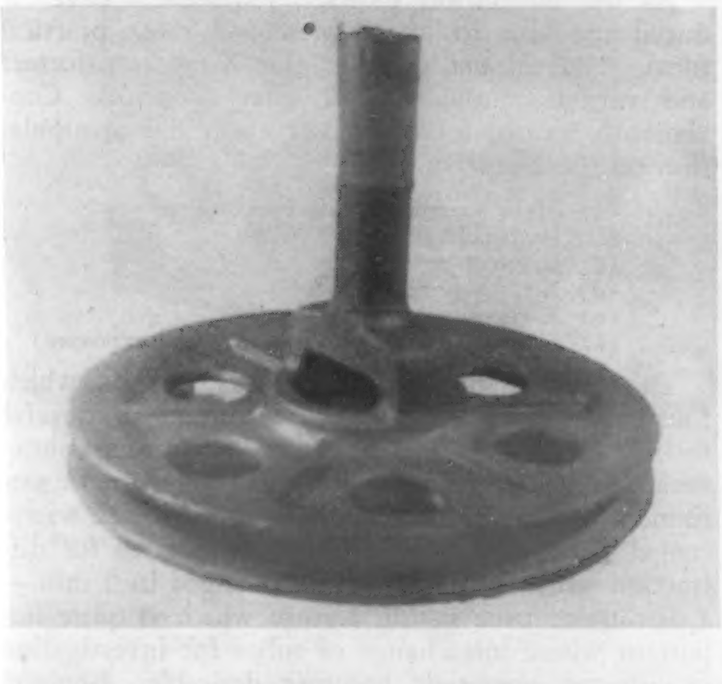
The casting being poured as the flask revolves in the casing.

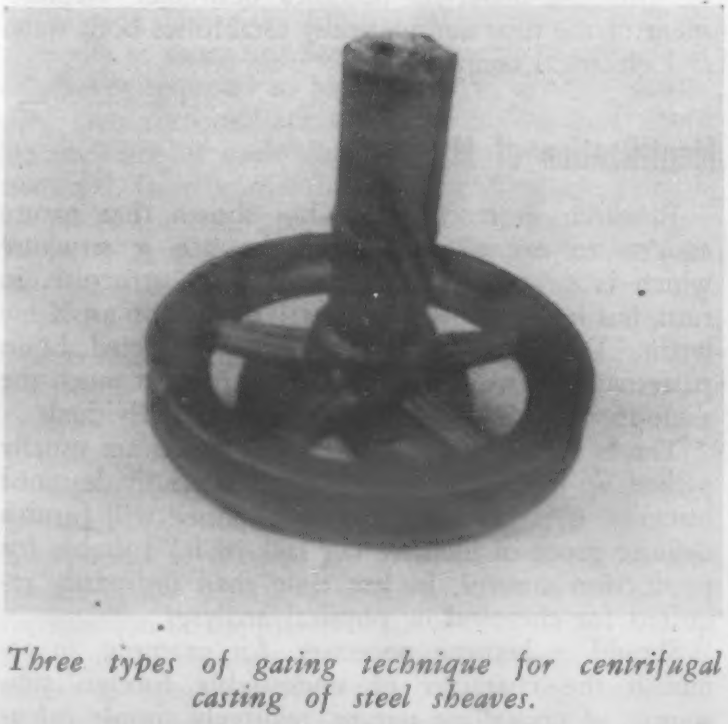
type has thin metal web sections which can be fortified by adding feeder pads of a half-round shape to both web sides, running from hub to groove, thus producing a solid groove metal." (Figures "A" and "B" show methods by increasing metal in spoke and by feeder pads.)

According to Mr. Johnson, sheaves with small diameter core through the hub are generally cast solid, better to feed through spoke or web to the rim. Medium sized sheaves, having hub diameter up

Discharging a mold from the centrifugal casting machine after pouring.







Three types of gating technique for centrifugal casting of steel sheaves.

to 6-in., are cast with one gate. Larger sizes are cast with two or more gates. Photographs show various gating arrangements. "In static casting, general practice places feed heads around the rims to assure sound groove metal. This occasions variations in rim temperatures, tending to cause warpage and cracks. This hazard is eliminated in centrifuging such castings," Mr. Johnson concluded.

High Speed Practice

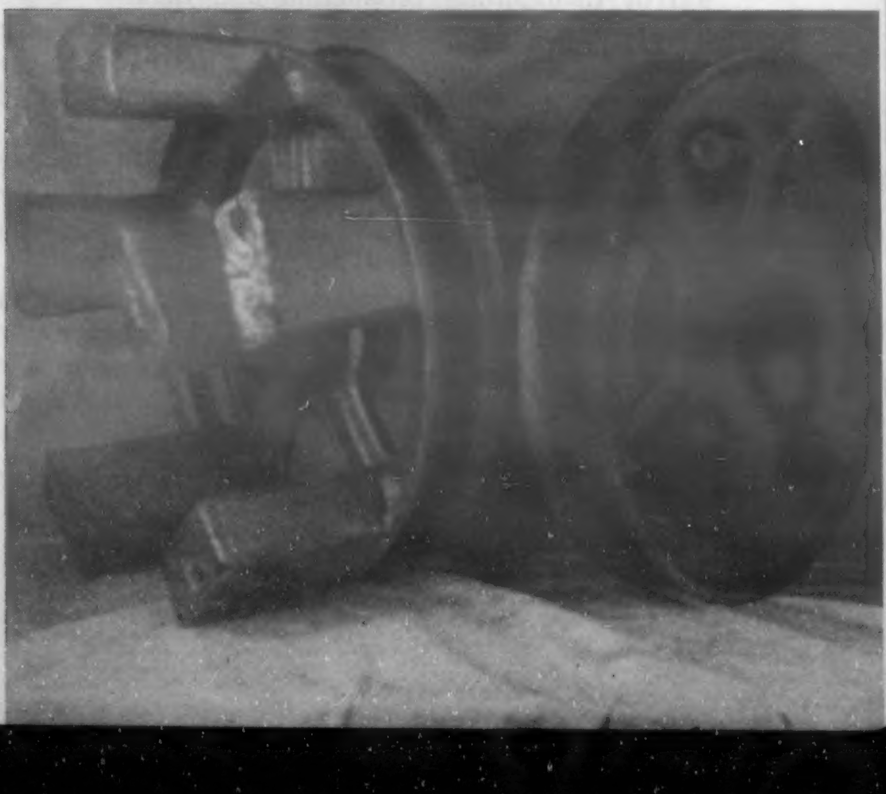
In the company's experience with the centrifugal casting of sheaves, from 24 to 36 molds are poured per heat, poundage varying from 3500 to 4500. The total elapsed spinning time is from 2 to 3 min. and the spinning speed is 150 to 200 rpm.

The average spinning speed for miscellaneous centrifugal castings approximates 600 surface feet per minute. Too great a centrifuging speed may cause peripheral cracks of a hot-tear nature created by tensile stresses thus set up. In some practice, the mold is entirely poured before being spun. In others, the practice is to vary the speed at intervals within the pouring cycle. The speed technique varies with the mold and casting design.

Certain it is that the pressure of centrifugal force has endowed the steel casting industry with significant advantages in certain types of design. Possessing the soundness of a forged or rolled section, such castings can be produced with less complexity of gates and risers, to achieve a better product. Nor is the centrifugal process as limited in application as supposed. Casting configurations, lighter weight castings, thin-sectioned designs, intricate, odd, non-symmetrical shapes are possible that were previously considered beyond the limits of centrifuging.

"In developing centrifugally cast steel castings, we feel that we are contributing to the war effort as well as advancing the technique of the steel casting industry, both by converting a larger percentage of our melt into castings so vitally needed during this emergency as well as by producing a very high quality steel casting," Mr. Johnson said. It is another evidence of good management thinking that has made the Oklahoma plant one of the most enterprising steel foundries, not only in the Southwest, but in the nation.

The sheave casting as cast by the static method (left) compared with the one (right) by the centrifugal process. Note possible crack in the line of the one at the left.



X-Ray Diffraction—An Industrial Tool

by J. S. BUHLER *North American Phillips Co., Inc., New York*

A METHODS ARTICLE

From the standpoint of the engineer and production man, X-ray diffraction has come a long way since the days when it was solely a metallurgist's research instrument. Today it is serving as a practical aid in rapidly identifying, comparing and analyzing raw materials, metals-in-process, finishes, etc. This article describes the equipment and discusses its industrial applications.

—*The Editors*

SHROUDED IN MYSTERY, X-ray diffraction has heretofore been avoided by many of the very industries to which it can be of greatest service, and upon mention has been rejected with a shrug of the production manager's shoulders as another involved piece of apparatus belonging properly in the realm of scientific research.

It may be true that only a scientist can understand and utilize for advancement of the frontiers of our knowledge the intricate concepts of atomic structures, reciprocal lattices, n-ordered reflections, Fourrier's analyses and the like—but these are of no immediate interest to those charged with the important everyday job of maintaining production and quality. Deep scientific knowledge is definitely not required for intelligent operation and valuable utilization of X-ray diffraction, which is now available in compact and simplified form for *practical* use.

The industrialist wants to know briefly how X-ray diffraction equipment works and what it will do for him. To answer these two questions is the chief aim of this article.

Fig. 1 shows a recently developed X-ray diffraction apparatus. In the hands of a semi-skilled operator (or in many cases, a trained unskilled person) it will perform identifications, comparisons, and even analyses which now require the services of chemists or other professional technicians.

As the illustration shows, its designers have reduced the unit to its simplest and most practical form. The cabinet contains the X-ray transformer and various automatic and safety controls. Conveniently located for easy observation and manipulation on the front panel are:

(a) Main switch (circuit breaker)
(b) High voltage control switch
(c) Kilovoltage adjuster
(d) X-ray tube current control
(e) X-ray tube milliameter
(f) Elapsed-time meter (tube life and exposure)

The cabinet supports four tracks (g) on which four cameras can be mounted. This unique and useful feature permits making four simultaneous exposures, thus conserving time and tube life. The tracks surround a housing (h) containing a 4-windowed water-cooled X-ray tube that is specially designed for diffraction work. The tube can be changed in 5 min.—a distinctive time saving feature which is quite important where interchange of tubes for investigation of different materials becomes desirable. Replacement of the tube automatically establishes both water and electrical connections.

Identification of Materials

Research in recent years has shown that nature assigns to every crystalline substance a structure which is unique and distinctive. Each structure, in turn, has its own special diffractive effect on an X-ray beam. Due to this phenomenon, diffracted beam patterns serve to identify the substances in much the same manner that fingerprints identify individuals.

Traces of the invisible diffracted beams are usually picked up by photographic film in specially-designed cameras. Often, the patterns so obtained will furnish definite proof of identity (or lack of it) suitable for production control, in less time than ordinarily required for chemical or physical analyses.

Should it become necessary, for example, to establish the character of undesirable foreign substances of crystalline nature, relatively simple calcu-

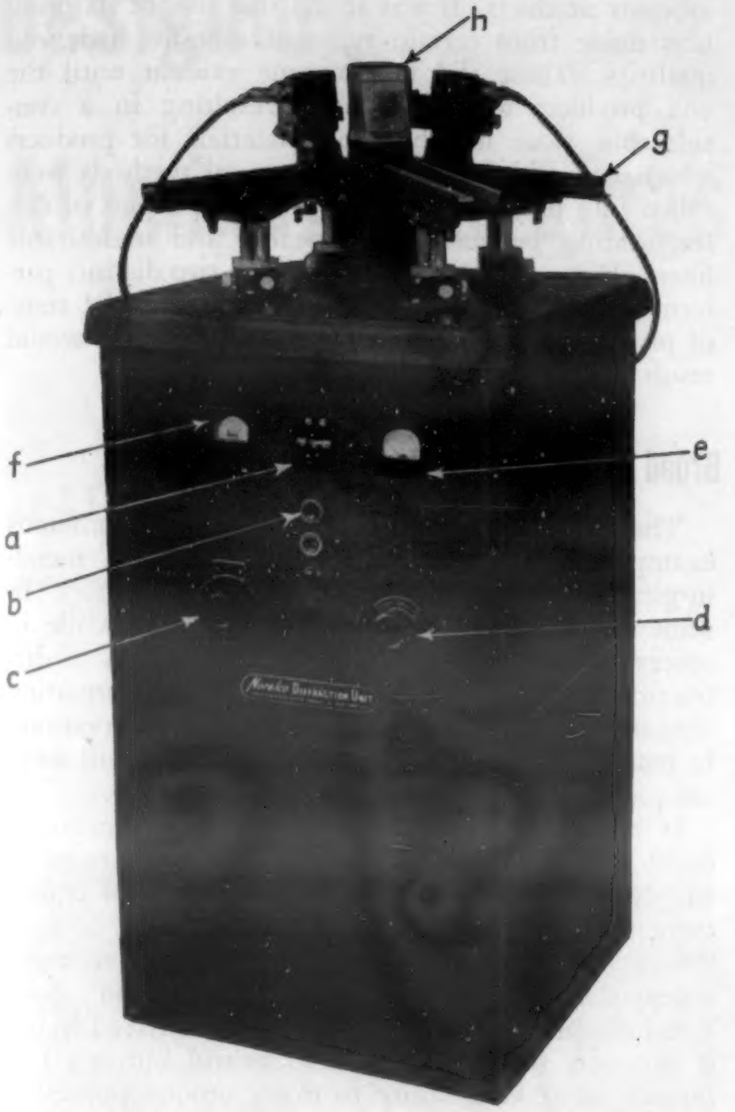


Fig. 1. Recently developed X-ray diffraction equipment which can utilize four cameras and carry on four analyses at one time.

lations based on these films will provide a powerful method of attack when used in conjunction with tabulated data available through American Society for Testing Materials. On the other hand, it may be necessary to ascertain that all of a series of crystalline substances required to secure an end product of desired characteristics are incorporated. In such cases, the presence of such desired substances may be determined from comparison of films taken from a sample of the later mix with master films.

Fig. 2 is a simple drawing showing how X-ray diffraction apparatus functions. This illustrates the circular camera for powder work. Arrangements are incorporated in the actual apparatus for rotating the specimen which comprises the substance to be investigated (in finely powdered form) in a capillary or coated on a fiber.

The principle of this camera is identical with that of all diffraction cameras, i.e. a callimated beam of X-radiation is allowed to strike the specimen, diffracted beams emerging at angles determined by the constitution of the material under test. After striking and passing through the sample, the primary beam enters a beam-removal tube which prevents the scatter resulting from impingement of the primary beam on air particles from darkening the film. This, in long exposures, may otherwise reduce contrast between the desired pattern and the background.

The film (which is punched at two points to accommodate the collimator and beam removal tubes) lies against the inner circumference of the camera as shown. A light-tight cover completes the assembly.

Type of Radiation Used

The type of radiation to be employed for a given material is determined from readily available accumulated data. Exposure times are frequently indicated, but may be modified by the user to meet his particular requirements. After exposure, simple procedures of development and fixing are followed, using equipment which can readily be installed in a small space in any plant.

Fig. 3 is a simplified representation of diffraction films as used for comparative work. Actual films may have many more lines, varying in intensity, but the principle is the same.

Let us assume that we have a product or raw material which analysis or experience have shown acceptable. From this we can establish a master film (a). This means that if we duplicate this pattern on sampling the new material has a corresponding structure. Now, if the product changes, or the raw material is procured from another source, or is suspected of being different, another pattern is taken. If it is like (b), there is a difference; if like (c) it is the same.

The fact that (b) is unlike (a) does not necessarily mean that the new material is inferior. Actually, it may be equal or superior on the basis of possible physical, chemical or field tests. In this case (b) may be established as an alternate or as a standard superseding (a).

The uses of this procedure as a control method are obvious. It will also be equally clear that a method of this nature does not require scientific knowledge. The standards can be established by technicians and inspectors having relatively little if any diffraction background, and the patterns can then be made by easily trained relatively unskilled personnel.

Should it be necessary to identify basic or admixed substances, it is necessary to have somewhat more training, but simple identification often can be made by employees having enough knowledge to employ simple formulae and ability to look up natural trigonometric functions in tables. Conversance with the vagaries of the product will also be helpful. In some instances it will be necessary to use diffraction as one of a number of methods of attack, or even the key where a number of factors or methods of analysis are involved. In such cases of course, consultation with diffraction specialists is advised. Problems of this type are of course of an advanced nature and beyond the normal scope of the apparatus as an industrial control tool.

For specific applications in metallurgical work, plastics and fibers, special cameras are available, each giving special advantages for a particular application. Included in these are focussing cameras, flat cameras,

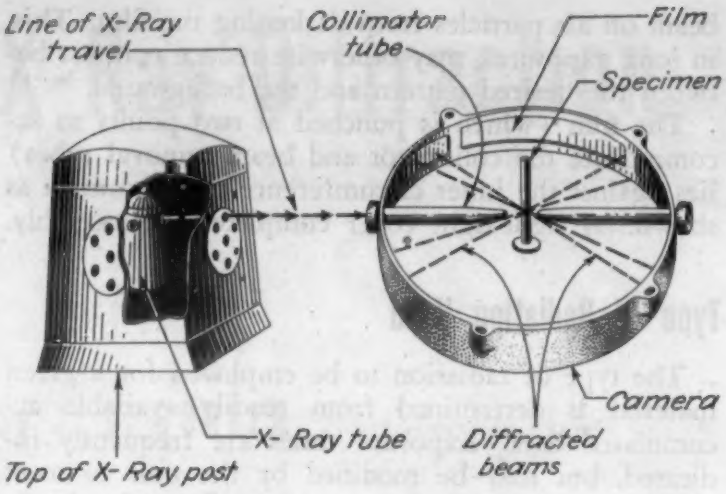


Fig. 2. A simple sketch showing the principles of operation for X-ray diffraction apparatus.

low angle cameras, etc. Through them comparative studies may be made. Degree of orientation may in many cases readily be ascertained.

Spectrometer

For certain types of work there is now available a Philips spectrometer which eliminates the need for film and development, giving directly the locations and intensities of the distinctive lines. This employs a Geiger-Muller tube coupled to an indexed arm. A meter in the tube output circuit gives not only indication of the presence of lines but serves to measure their intensity. Thus, as the specimen and Geiger-Muller tube are rotated relative to each other, with the specimen in the X-ray beam, it is possible to plot the locations of lines and their intensities quickly.

This method also lends itself to rapid acceptance or rejection work, for a single line can often be employed to serve as a criterion, its presence or absence being all that is required for a decision. This apparatus can be used by an unskilled operator, once it is properly set up.

A concrete example of the utility of diffraction was recently provided in the case of a company making asbestos products. It was found that one of its products made from certain types of asbestos had poor qualities. These did not become evident until the end products were fabricated, resulting in a considerable waste in labor and materials for products which had to be discarded. Chemical methods were called into play but failed to provide a means of differentiating between the desirable and undesirable fibers. Diffraction was employed and two distinct patterns resulted, making it possible at the initial stage of production to select the type of fiber which would result in the better final product.

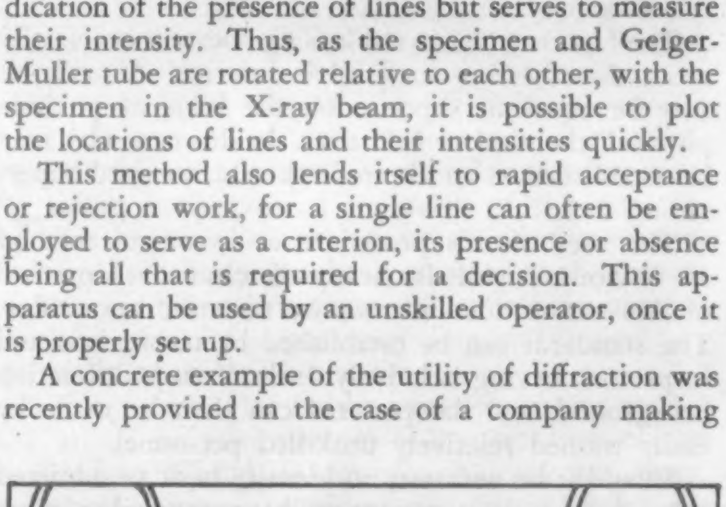


Fig. 3. Drawings show sample X-ray films as used in diffraction analysis work.

Broad Field for Its Use

The field for diffraction is replete with numerous examples of differentiation in the chemical, metallurgical, ceramic, petroleum and dairy industries. In some cases, the method has been clear cut while in others it has been necessary to couple studies of diffraction patterns with related scientific information obtained through physical and chemical observations. In many cases however, a simple procedure will serve adequately as a method of control.

It has been the purpose of Philips engineers to build this equipment so that it may be operated as simply as other forms of production control equipment. As at present executed, it provides a convenient tool for the average plant when used under supervision of a technically inclined person. Such a technician, if alert and progressive, can readily use it not only for inspection and control but can frequently extend its utility to many unique phases of analysis peculiar to his particular plant's products and functions.

Once installed in the larger plants, it will also be available to research men for advanced work in improving products and their performance. In many cases, due to the fact that four camera positions are supplied, research investigations can be progressed at the same time ordinary control and analytical work is conducted. Thus, there is available a piece of apparatus which fulfils a dual function in a single installation.

Examples of the diversity of problems in which diffraction has proved its value are given in the following list, which represents but a few applications of this art to industrial processes.

1. Establishment of identities in ceramic clays
2. Dairy products
3. Quality tests on soapstone before firing
4. Determination of covering quality of paint pigments
5. Differentiation of natural and artificial pearls
6. Identification of aluminum oxide modifications
7. Differentiation of inorganic fibers
8. Metallic deposition in formation of metallic carbides
9. Determination of character of metallic films

From the foregoing it must be concluded that X-ray diffraction should take the position as an industrial tool which it so definitely deserves. Application analysis prior to adoption is of course important, but industry can no longer afford to overlook the potentialities of X-ray diffraction as a means of maintaining product quality, particularly where competition is keen.

Designing Aluminum Forgings

by STANLEY V. MALCUIT

Aluminum Co. of America, Pittsburgh

Fig. 1. A group of miscellaneous forged parts. Aluminum forgings are primarily used in parts heavily stressed in fatigue and impact, or where space limitations do not permit the use of castings.

A MATERIALS-AND-METHODS ARTICLE

Aluminum alloy forgings are playing a vital role in shaping Victory, and no one doubts that their enormous expanded production facilities will find wide post-war use. Written primarily for design engineers but of obvious interest also to production men, this article presents the principles of aluminum-forging design and provides various design-detail recommendations for achieving highest quality aluminum forgings and for simplifying their production as well.

—The Editors

ONE OF THE MOST OUTSTANDING industrial achievements of the present world war has been the huge expansion in the use of aluminum alloy forgings and the facilities for producing them. From a total monthly production of a few hundred thousands of pounds of pre-war demand, military requirements have risen to a peak in excess of 25,000,000 lb. per month, involving many thousands of entirely new parts, for each of which elaborate tooling has had to be provided.

Such an expansion would have been considered a noteworthy record in the case of almost any standard product, but when it is realized that forgings are one of the least standard of all products, that they are made on all kinds and sizes of forging equipment and that the problem of die and tool procurement is of the most difficult and complex nature, this accomplishment is truly astonishing.

Advantages Over Castings

Aluminum alloy forgings offer the same general advantages over aluminum castings and other "built up" wrought products as steel forgings or brass forgings offer over the same metals in cast form, or as built-up, riveted, or welded structures. They are a "one-piece" product fashioned closely to theoretically ideal shapes and sections. They are "wrought material" of a high degree of integrity and uniformity, heat treated to the maximum physical properties which it is possible to develop in the particular alloy and piece in question.

In addition to these general advantages, aluminum forgings possess many peculiar and specific properties which dictate their use for many applications. Among these may be mentioned high thermal and electrical conductivity, excellent machinability, resistance to corrosion and fatigue, and a rather wide range of expansion characteristics.

Aluminum forgings are produced for the most part on all types of standard forging machinery, steam hammers, board hammers, presses, mechanical and hydraulic, upsetters, etc. Die design and general tooling, however, are necessarily more or less peculiar to the product, *i.e.,* its working temperature, expansion characteristics, lack of scaling, affinity for die steels, etc.

It is the purpose of the present article to discuss some of these features having to do with forging design with the thought that such a discussion may prove helpful to those interested in the use of this product.

Fig. 2. Workmen are removing an aluminum alloy crankcase from the forge.

It may be that the part will encounter severe corrosive conditions and, in this event, the designer must select the alloy which will have satisfactory life under service conditions. The design of the forging will also play an important role in resisting corrosion, as correct design eliminates such difficulties as moisture pockets.

In some forgings, the ultimate use of the part may require the best electrical conductivity possible. Alloys containing elements which show substantial changes in solid solubility with rise in temperature may show corresponding variations in conductivity, depending on their thermal treatment. In forgings requiring good electrical conductivity, selection of the proper alloy and correct design will be determining factors.

Design Factors

The first step in designing an aluminum forging is to determine the conditions which the part has to meet in service. It must be designed to perform a particular function. If this function is understood, then the most suitable alloy and the most efficient design may be utilized to provide dependable performance.

The loading of the part must be carefully considered. The type of loading will greatly influence the percentage of weight saving that is possible. In some cases, the light weight of the aluminum part itself will reduce the stresses which it has to withstand. If the part is subject to cyclic loading or vibration, the fatigue properties of the material may be an important consideration. It may be that the part is subject to static stresses of either tension or compression, in which case the tensile and compressive properties of the material are important. Stiffness may be required in the finished part, or high resiliency may be needed to absorb impact stresses. Whatever the loading may be, the designer should have a clear understanding of it and design the part so that it is capable of meeting the prescribed conditions.

The temperature conditions which the part has to meet is another important factor. At elevated temperatures, the tensile strength, yield strength, and modulus of elasticity of aluminum alloys are lower than they are at ordinary temperatures. With increased temperature, fatigue strength decreases rapidly and it is necessary to give due consideration to the operating temperature in working out the best design for the part.

Another factor which the designer must consider is the amount of wear or abrasion the part will be called upon to withstand. Hardness and wear resistance vary in the different alloys and the designer must make allowances in the forging to insure the required hardness and wear resistance.

Fig. 3. A basket of aluminum alloy forgings is being lowered into a quenching tank after heat treatment. Upon removal from the tank, these forgings will be given a further aging treatment which develops maximum properties.

In certain parts, such as forged pistons, thermal properties are important factors for the designer to consider. Thermal conductivity and thermal expansion vary depending on the alloy. The design of the part may influence the effect of these properties. Both of these factors are important considerations if the forging is to meet service conditions.

Any one of the above conditions may be the controlling factor in designing an aluminum forging, or several factors may combine to dictate the selection of the alloy and the design principles. In most cases, the latter will be true and the designer must carefully weigh each factor to insure the best result.

As soon as the designer thoroughly understands the function of the forging, he must select the alloy which, in his opinion, will give the best service under the existing conditions. In general, nine aluminum alloys are used for forgings. The Table gives the typical mechanical properties of these alloys.

The Forging Alloys

The strongest forging alloy in general use is 14S. It finds wide application where high strength and good resistance to corrosion are desired. It is, however, one of the more difficult alloys to forge. When using this alloy, tolerances must be closely adhered to and the dies must be correctly proportioned to permit ready flow of the metal in forging.

Alloys 25S and 17S are used whenever moderate strength is required. Alloy 25S is easier to forge than 17S, but the latter has superior machining qualities and better resistance to corrosion. One of the most easily forged alloys is A51S. It finds it chief use in the production of large and intricate parts, where the highest mechanical properties are not required.

Unusually severe corrosive conditions may dictate the use of alloy 53S, which is similar to alloy A51S but is much more resistant to corrosion. Alloys 32S and 18S are used for parts, such as pistons, in which the retention of strength at elevated temperature is essential. Alloy 32S also has the lowest coefficient of thermal expansion of the wrought aluminum alloys.

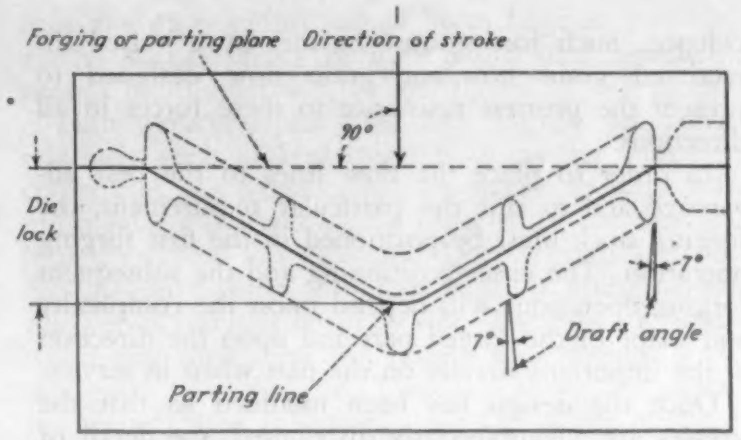


Fig. 4. Typical cross section of forging die, illustrating forging plane, parting line, and draft angle. Notice that the parting line runs through the profile of the forgings web.

The ease with which alloy 11S can be machined makes it best suited for certain purposes where machining costs become a determining factor in the choice of the alloy. Although they are not generally classed as forging alloys, 2S and 3S are occasionally used for forgings which require excellent welding characteristics as well as very high resistance to corrosion.

Shape and Operation — Sequence

Once the alloy has been selected, the general proportioning of the forging is begun. By careful analysis based on previous experience, it is generally possible to design the piece so that it will have adequate strength and, at the same time, meet the conditions of forging for that particular alloy. It is also possible for the designer to proportion the dies so that the metal flow will give maximum metal properties at the points of maximum stress resulting from service conditions.

The proper working of aluminum changes the grain structure of the metal and produces a final material which has excellent mechanical properties. The high strengths which result from such grain flow can be utilized to best advantage in properly designed forgings. It may be that the stresses applied to many parts do not have a single directional in-

Table of Mechanical Properties of Aluminum Alloy Forgings[1]

Alloy	Minimum Specification Values					Typical Values (Not Guaranteed)	
	Tension[2]			Hardness[2]	Shear	Fatigue	Density
	Yield strength[1] (Set—0.2%), p.s.i.	Ultimate strength, p.s.i.	Elongation,[1] per cent in 2 in.	Brinell, 500-kg. load, 10-mm. ball	Shearing strength,[1] p.s.i.	Endurance limit,[1] p.s.i.	Lb. per cu. in.
11S-T	34,000	55,000	12.0	90	31,000	13,000	0.101
14S-T	55,000	65,000	10.0	130	45,000	16,000	0.101
17S-T	30,000	55,000	16.0	100	36,000	15,000	0.101
18S-T	40,000	55,000	10.0	100	38,000	14,500	0.103
25S-T	30,000	55,000	16.0	100	35,000	15,000	0.101
32S-T	40,000	52,000	5.0	115	38,000	14,000	0.097
A51S-T	34,000	44,000	14.0	90	32,000	10,500	0.097
53S-T	30,000	36,000	16.0	75	24,000	11,000	0.097
70S-T	40,000	50,000	16.0	85	37,000	19,000	0.107

[1] These properties apply to forgings up to 4 in. in diam. or thickness. Long axis of test specimen taken parallel to direction of grain flow.
[2] Tension and hardness values determined from standard ½-in. diam. test specimens. Values in compression at least equal to values in tension.

cidence. Such forces must be met by a varied directional grain flow, or grain flow designed to present the greatest resistance to these forces in all directions.

In order to place the flow lines to the best advantage and to suit the particular requirement, the forging stock must be positioned in the first forging operation. The exact positioning and the subsequent forging operations will depend upon the complexity and shape of the forged part and upon the direction of the important stresses on the part when in service.

Once the design has been modified so that the stresses are advantageously distributed, the detail of the design may be worked out. It is necessary that the designer incorporate factors into the mechanical design of the forging that tend to enhance its strength as well as to increase economy in cost of the forging and subsequent processing operations such as machining, heat treating, and assembly.

The designer must first choose the forging plane, which lies at right angle to the direction the reciprocating die travels (Fig. 4). It must be chosen with considerable care in order to produce forged parts having greatest functional value and requiring little or no subsequent machining.

The parting line is the line along which the lower and upper dies separate (Fig. 4). It may be straight and lie along the forging plane; or it may be made irregular to accommodate bends, lugs, webs, and the like in the forged part. It is often possible to design a forging so that all the impression is within one die. Single dies of this sort may, nevertheless, require broken (irregular) parting lines.

It is generally preferable to run the parting line through the profile of the forgings web (Fig. 4)—if there be a web—and the profile need not be on the center line. Naturally, this rule cannot be followed in the case of single dies, for obvious reasons.

When the parting line of the forging dies is irregular from any view, the resultant "meshing" of the dies is called die lock. When choosing the forging plane, the designer should be careful to include the effects of die lock in his calculations to avoid unbalanced sidewise loads on the forging equipment.

It will frequently be found more economical and practicable to bend a part after it has been forged, rather than to forge the bend into the part. Bending may be done while the metal is still hot, or even after it has cooled, providing the degree of deformation is not severe. In any event, the designer should make allowances for such bends.

Fig. 5. A die sinker is polishing the surface of a crank-case forging die. This operation removes all tool marks so that a better product is obtained and the forging can be readily removed from the die.

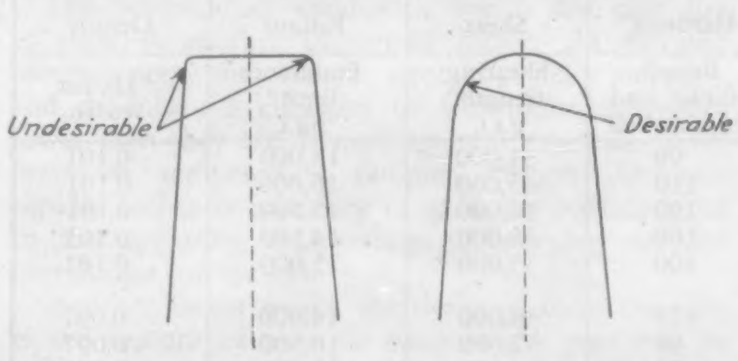


Fig. 6. Generous radii should be provided on relatively wide ribs so that the metal will flow easily into the deeper crevices.

Dimensions

In order to prevent the forging from sticking in the die, a draft angle of approximately 7 deg. must be provided (Fig. 4). This figure will be suitable for average-size plugs or projections, but very deep cone frustums will require a larger taper. Since draft

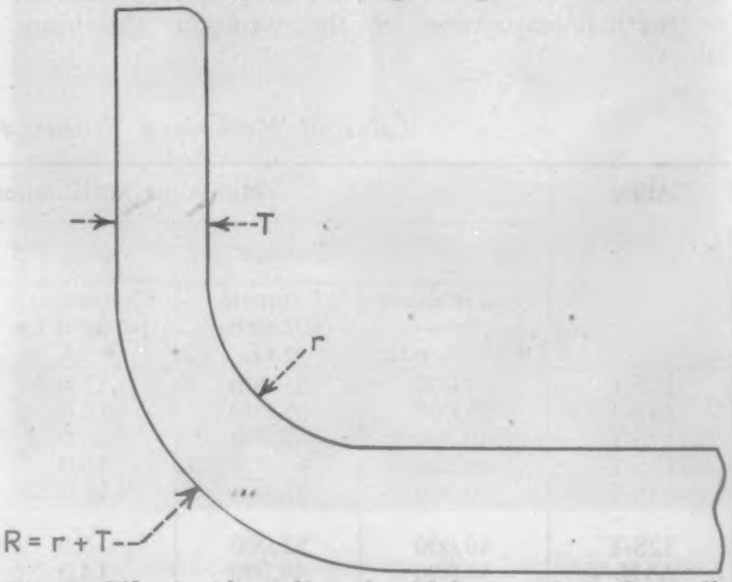


Fig. 7. The inside radius should be equal to the wall thickness on bath-tub forgings ($r = T$); the outer radius should be large and at least equal to the fillet radius plus the thickness of the thinner web.

angle is a function of die motion, it is always calculated from the forging plane and the draft starts from the parting line.

The size of radii and fillets should be as large as possible to assist the flow of metal through the change in direction. Forging defects such as cold shuts, laps, broken fibre structure, and unfilled sections as well as increased die wear are the result of radii and fillets which are too sharp.

Corner radii of sufficient magnitude must be provided on forgings with deep ribs if cracked dies are to be avoided. Flanges should be as thick as possible to reduce die breakage and die cost, but, on the other hand, flange thickness should also be kept at a minimum because of weight and other factors. The designer must exercise considerable ingenuity if the forging is to perform its proper functions and still be practicable from a manufacturing standpoint.

On relatively wide ribs, where a flat with minimum radii at the corners would be possible, the added difficulty of forcing the metal into such corner radii makes it desirable to design these ribs with a full radius at the top (Fig. 6). On bath-tub type forgings the inside edge radius should be equal to the wall thickness whenever possible. (Fig. 7). Corner and edge radii should remain constant along ribs and flanges in order that die sinkings may be done with one tool, even though the section tapers in height.

Fillets should be as large as the design allows, as small fillets restrict the flow of metal into the deeper crevices of the die and cause excessive die wear at the fillet, or die breakage because of high pressure needed to force the metal over the fillet (Fig. 9).

Fillet radii that vary will cause an increase in die price because they must be tapered by hand. It is usually feasible to retain a constant radius over most of the length of a moderately changing section without penalizing the design, and this should be done whenever possible (Fig. 11). On bath-tub type forgings, the outer radius should be as large as possible, and at least equal to the fillet radius plus the thickness of the thinner web (Fig. 7).

Fig. 8. Designers have been instrumental in making America's war equipment the finest in the world. This die designer is making a template from a part drawing which will be used to give the outlines of the impression that will be milled in the die block.

Thin webs dissipate their heat rapidly because a relatively great area of metal is in contact with the cooler dies. As a result, they are harder to forge and die breakage is common. In many cases, the dies are heated to avoid this difficulty. Deeper cavities in the dies may fill or offer strong resistance to filling before the web is brought down to size. The flow of excess metal may then shear the various sections into separate parts (Fig. 12). To overcome these difficulties, the web may be thickened from the center outward and the fillet radii increased (Fig. 12a), or a large portion of the web punched out (Fig. 12b).

The latter method permits using as a gutter that portion of the web which later will be punched out. An unsupported thin edge around the punched-out section may not meet strength requirements, and an improved section may be obtained by beading the cut-out. On small parts with fin-like projections from a globular center, the fin may be forged to a minimum thickness of 1/16 in. with a width of no more than one inch (Fig. 13).

Holes in lugs require the forging of a local depression until a web of ⅛ to ¼ in. thickness remains. While the metal is hot, the web is punched out. To avoid distorting adjacent sections of the forging during the punching operation, considerable area should be left between the flange and the punched hole. Holes should start at the point of tangency of the fillet and the web (Fig. 14); they should not include any of the fillet and draft of the flange. When an irregular hole is to be punched in a web, the final trimming of the flash and web can be accomplished more easily if a small amount of the web is left around the inside of the part to provide a bearing to hold the forging during trimming operations.

Tolerances

The variations permitted from the given or normal requirements are known as tolerances. Thickness tolerance applies to the overall thickness of the forging, and varies with the net weight or overall dimensions of the product being fabricated. It is applied in a direction perpendicular to the parting plane, or parallel to the ram travel, and is figured separately and independently of any other tolerance.

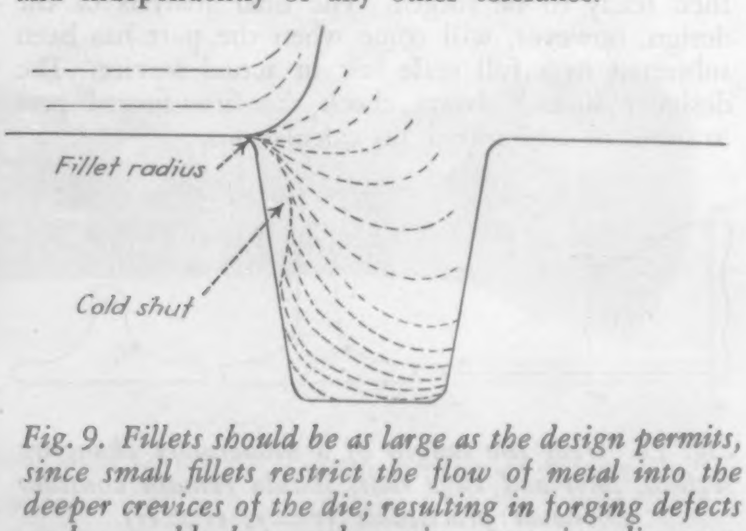


Fig. 9. Fillets should be as large as the design permits, since small fillets restrict the flow of metal into the deeper crevices of the die; resulting in forging defects such as cold shuts and causing excessive die wear.

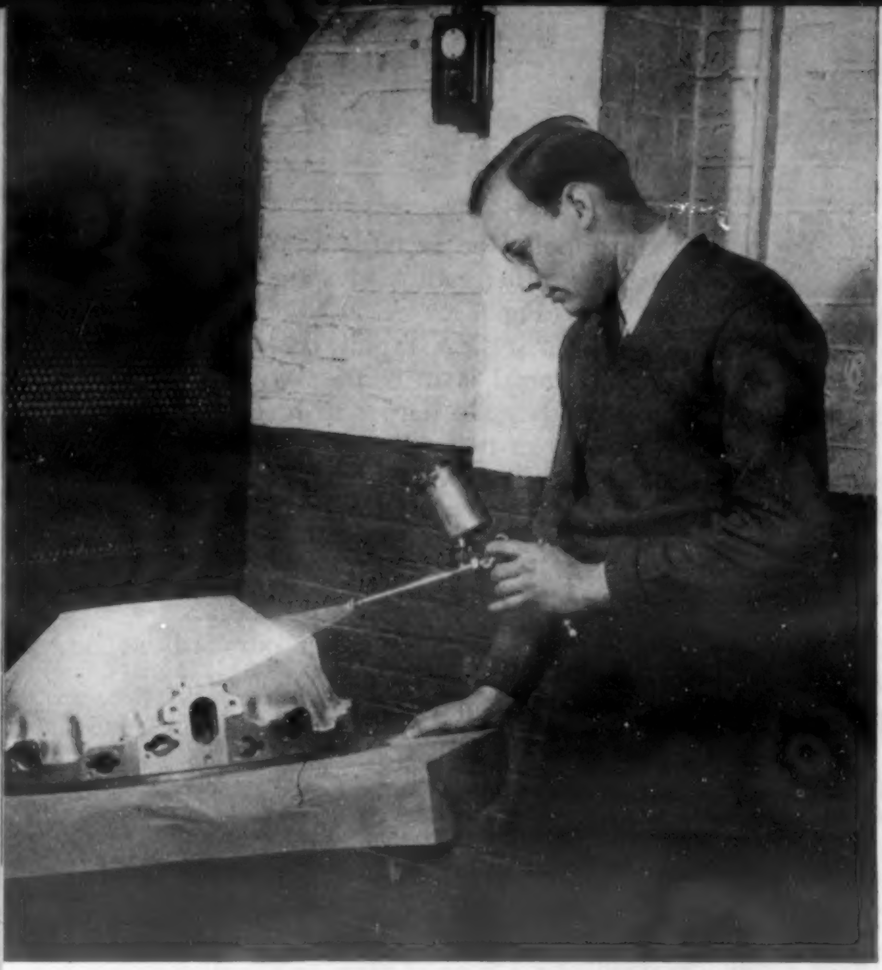


Fig. 10. Spraying "Stresscoat" lacquer on an aluminum airplane nosepiece. The part will then be subjected to a load simulating the condition which the part must withstand in actual service. Once the "stress concentration points" have been located, it will be possible to determine how redesigning the part can increase strength at the weak point.

A slight misalignment of the forging dies which results in a shift of one part of a forging along the parting line from its relative position to the other part of the forging is called mismatch. A dimensional contraction in all directions in a forging resulting from the cooling of the metal is called shrinkage. The designer should add enough metal to compensate for shrinkage and mismatch, but the allowance should never be the sum of the two. The allowance is governed by the factor which requires the greatest tolerance in a given direction. Stock for machining must be provided in addition to shrinkage and mismatch tolerances. The minimum machining allowance on small and medium-sized forgings is 1/16 in.; for large forgings, 1/8 in.

After the design has been detailed so that it can be made practicably and economically, the part is then ready to be forged. The final analysis of the design, however, will come when the part has been subjected to a full scale test in actual service. The designer should always check the first forged part in order to substantiate his calculations.

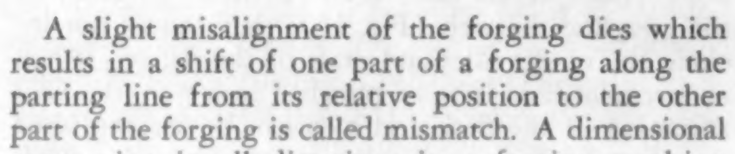


Fig. 11. Over the length of a moderately changing section, fillet and edge radii should remain constant whenever practicable ($r = r$; $r_1 = r_1$).

Stresses and Strains

Whenever the part fails in service because of inadequate design or whenever a completely new forging is to be developed, a stress analysis should be conducted to determine the distribution of stresses. An abrupt variation in which the intensity of stress increases greatly within a very short distance is described as stress concentration. Stress raisers include irregular surface contour and metallurgical irregularities such as inclusions and porosity. The endurance limit of a part subject to repeated loading is greatly lowered by small scratches resulting from handling or machining.

In order to distribute the stresses in the design that has been proportioned according to experience and mathematical calculations, a stress analysis by strain measurements must be conducted on a full size cast part. A cast part will serve as a satisfactory test specimen even though the part is to be forged, since the modulus for all aluminum alloys fabricated by different methods is substantially the same. By using a casting, a design can be developed without the expense of elaborate forging dies.

The recommended procedure to be followed in analyzing the part is to make a strain analysis after coating the entire specimen with a brittle lacquer of the Stresscoat type, and then loading it so as to simulate the conditions of loading found in service. This analysis will give the strain pattern showing the directions of principal strains. The next step is to use a second coat of lacquer on the areas of particular interest. By applying the load in steps, the first crack appearing in the coating at different locations will indicate where the strains are of high order.

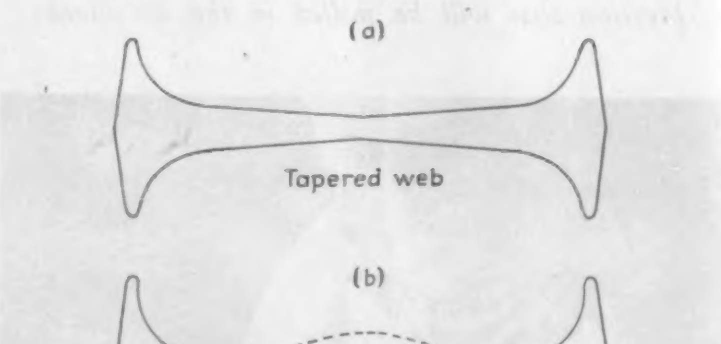


Fig. 12. Deep, thin webs are hard to forge and the metal often flows straight through to the gutter. To overcome this the web may be thickened gradually from the center outward (a) or a large portion of the web may be punched out (b).

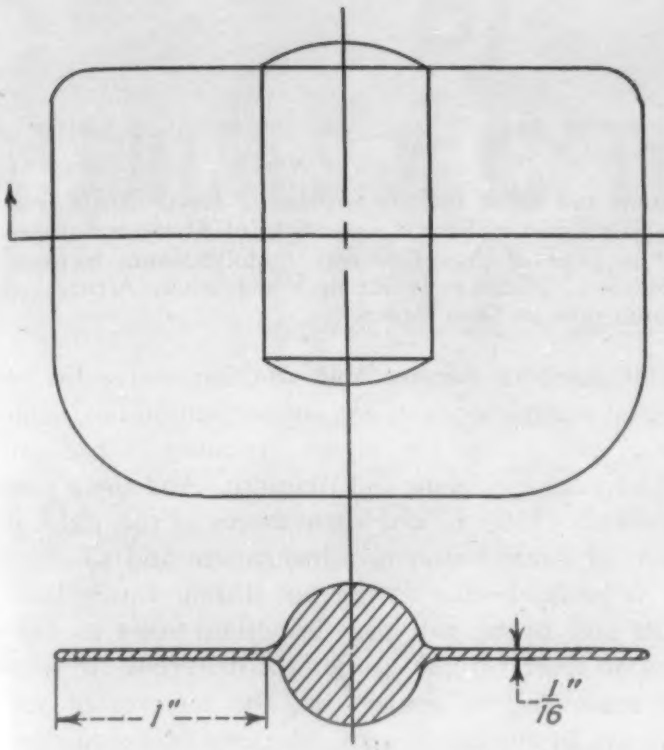


Fig. 13. On small globular-centered forgings, the projecting fin may be forged to a minimum of 1/16 in. with a width of no more than 1 in.

After the brittle lacquer method has brought out the regions in the structure where the strains are of a high order, a suitable type of strain gage must be employed to determine the relationship between the load and the strain or, in other words, to determine such high static stresses quantitatively. With the brittle lacquer test revealing the direction of the principal strains, strain gage measurements are taken, one parallel to the principal strain and one at right angles to it, and from these measurements the stresses are calculated mathematically.

It is often possible to gain considerable information by taking strain gage readings at successively increased loadings. It may be found that the yield strength of the material has been reached in some regions of the structure at relatively low loads, and as a result of yielding at these points, the strains at other points might cease to change appreciably with increasing load.

In parts subjected to elevated temperatures, the distribution of stresses can be considerably different at operating temperatures than the distribution of stresses in the part at room temperature. As the temperature increases, certain stresses may decrease, while at other locations, the stresses may increase with increased temperature.

If the investigation of the stress distribution in the part reveals a high stress concentration over a limited area, the solution to the problem is not found by adding metal, but rather by improving stress distribution. A high surface stress, for example, is likely to occur at the top of a rib which is tapered to a narrow section. In such a condition, the solution is to reduce the height of the rib by cutting away the highly stressed metal, thus redistributing the stress. The removal of a slight amount of metal on the top of a rib will decrease the high surface stress considerably, and the portion of the load formerly carried by the highly stressed metal will then be distributed over a relatively much larger area.

As the analysis warrants changes, the part is redesigned until the stresses approach a safe level with a minimum of stress concentration. In this way, defects in forged parts are quickly remedied and new designs are readily proportioned.

By using the procedure which has been outlined in the text, designers of aluminum forgings have been able to meet military demands on schedule as well as to save considerable time and money in the development of new and improved forging designs.

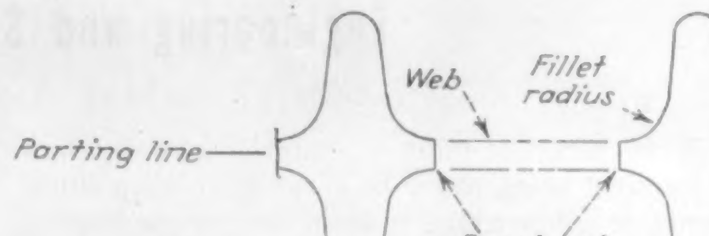


Fig. 14. When holes are to be punched in webs, they should start at the point of tangency of the fillet and the web.

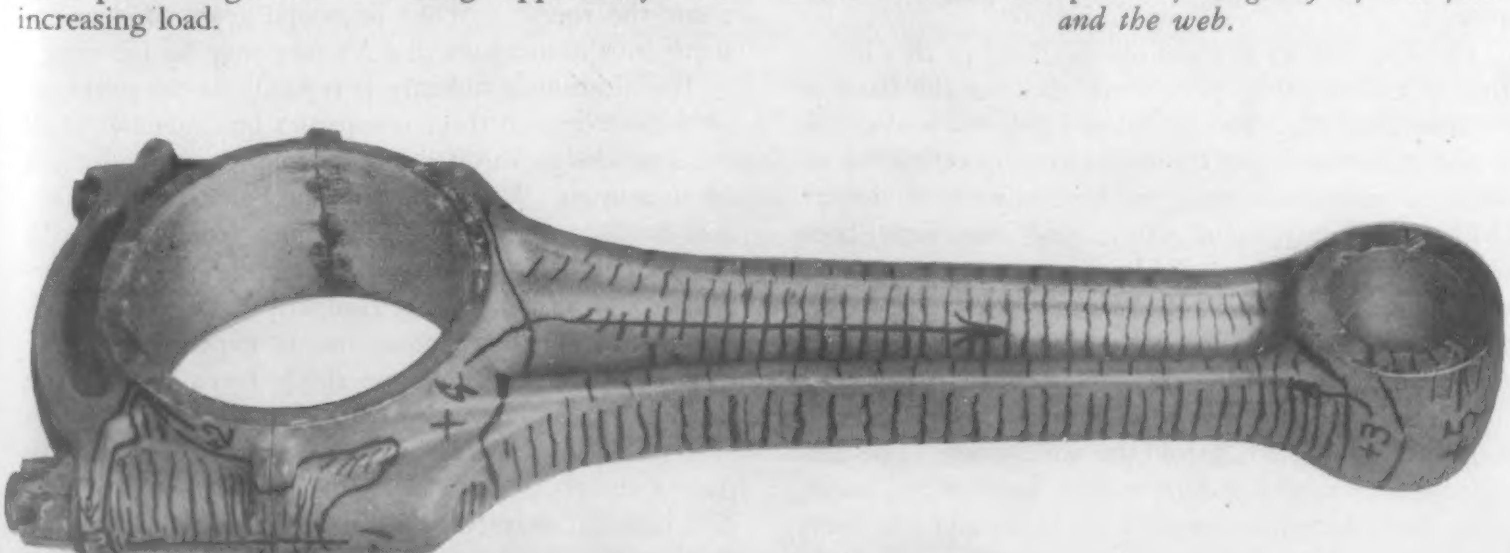


Fig. 15. Aluminum connecting rod which has been subjected to inertia loading. Stresscoat pattern is clearly illustrated.

(Continued from page 1295)

With the exception, perhaps, of oil and coal, Africa is probably the world's largest reservoir of commercially important minerals. In the last forty years the world has extracted more minerals from the earth than in all preceding history. In Africa, last continent to be settled by Europeans, most minerals are still in the ground. Africa has tremendous reserves of high grade copper ore in the Katanga fields of Northern Rhodesia and the Belgian Congo. From Africa comes all but a small percentage of the world's famous diamonds and almost half its gold. Large quantities of iron ore and bauxite have been found, some of it as in Sierra Leone, near the coast. On the Gold Coast is the world's largest manganese mine and Africa is a leading supplier of this material. Southern Rhodesia is the world's largest producer of chrome ore and the second largest source of asbestos. Nigeria alone produced an amount of tin in 1942 almost equal to the requirements of Great Britain and, with deposits in the Belgian Congo and Ruando-Urandi, the continent as a whole could become a major producer of that metal. Africa produces almost half the world's cobalt and uranium and about half its vanadium. North Africa, economically a part of Europe rather than of Africa, is Europe's chief supplier of phosphate rock. Molybdenum is found in Morocco, platinum in Ethiopia and South Africa, and titanium ores in West Africa.

This presents a formidable and impressive list of essential materials—iron ore, copper, aluminum, manganese, chromium, tin, cobalt, uranium, vanadium, molybdenum, platinum and titanium. And there may be others. Closer to our own shores is the mineral wealth of Brazil—iron ore, manganese and so on.

It is probable that in the not distant future both Africa and Brazil will play important roles as suppliers of several highly important materials. It is at least reassuring to realize that the reserves of the world are by no means near the point of exhaustion. Those of Africa and Brazil will either be obtained or other sources will be discovered—at possibly increased cost, however, over present levels.

—E. F. C

Engineering and Science Were Ready

With charges of military unpreparedness and lack of foresight being tossed back and forth by political parties, it is heartening to learn that in one respect, at least, the United States was ready for any emergency. Our engineers and research workers had built up a bank of factual information that permitted them to find quickly the answers to military or production problems, and to make America the arsenal of democracy.

Dr. Zay Jeffries has already outlined in this magazine (October 1943, page 764) the way the bank of metallurgical engineering "know-how" made available to the government in the national emergency the results of research costing many millions of dollars. Skilled technical men, who could not have been tempted by any salary within the gift of the government, were given leaves of absence by their companies to go to Washington and help solve the urgent design and production problems that war thrust upon us.

At the National Electronics Conference in Chicago, Ralph R. Beal, of RCA, told the same story. "The preparedness picture was dark indeed, but for one heartening fact: American research scientists and engineers were ready. Men equipped with knowledge and experience gathered so painstakingly by research and engineering—made an unbeatable combination when teamed with the great resources of this country and the American will to win. . . . When the war came to America, we were suddenly awakened to the realization that science must be directed to warfare if we were to defeat an enemy fortified by ingenious scientific applications. Quickly America's men of science rallied to national defense; industrial research was organized to function as a unit with one aim—to win the war. . . . In war, the scientist and the engineer answer the call in the laboratory and in the field. . . . They study the techniques and devices of the enemy; they build superior weapons to combat and to overcome the foe. . . . They telescope years of development into months, so that Victory may be hastened."

The aluminum industry is typical. At the outbreak of the war two or three companies held practically all the knowledge this country possessed of production of aluminum. When the government decided that it was necessary to expand aluminum-producing facilities, skilled technicians from Aluminum Co. of America were assigned by that company to serve the government with their indispensable experience. Dow Chemical Co. did the same thing for a part of the magnesium program.

In many other fields we see corporations waiving patent rights so that the results of their own expensive research may be available to the nation, free of charge. Wright Aeronautical Corp. had produced an aircraft bearing of superior wearing qualities, but it was made available to the entire aircraft program of the government at the beginning of the war.

This has been the engineer's contribution to the war—a contribution impossible to evaluate fully even now, but certainly a vital one.

—K. R.

MATERIALS & METHODS MANUAL

2

This is the second in a series of Manuals on engineering materials and production methods, published at periodic intervals as special sections in Metals and Alloys. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal-forms or with essential principles, best procedures and operating data for performing specific metal-working processes.

Powder Metallurgy

by Earle E. Schumacher
& Alexander G. Souden, Metallurgists,
Bell Telephone Laboratories, New York

with an Appendix by The Editors

The war emergency has focussed attention on the frequent ability of powder metallurgy to make parts faster or cheaper or with less waste of materials and machine-time than other methods, and on its penchant for providing special types of materials impossible to make otherwise. This Manual presents a comprehensive, concise and authoritative review for design and production engineers of the technical nature, commercial significance and practical application of this fast-changing field. To the main body of this material (which is also being published simultaneously by "Bell System Technical Journal") the editors of M & A have added an Appendix of specially assembled data on the types and manufacturers of powders, processing equipment and parts, intended to assist engineers in locating sources for these items for their present and post-war products.

Contents

Metals and Alloys, November 1944

MATERIALS & METHODS MANUAL 2

Introduction

This correlated review is an attempt to present some of the more common and broadly significant aspects of powder metallurgy in order to acquaint engineers with an increasingly important production method, and to provide a digest of selected pertinent references that could otherwise be had only from many different sources.

Basically, the art of powder metallurgy deals with the preparation of metal powders and their utilization. This is a general description, however, and covers not only the so-called *metallurgical* field, but also the paint and pigment and other more strictly *chemical* industries. As a more pertinent definition, the following has been suggested: "Powder metallurgy is the art of producing metal powders and shaped objects from individual, mixed, or alloyed metal powders, with or without the inclusion of non-metallic constituents, by pressing or forming objects which are simultaneously or subsequently heated to produce a coalesced, sintered, alloyed, brazed, or welded mass, characterized by the absence of fusion, or the fusion of a minor component only."[1]

In the past few years, powder metallurgy has received considerable attention, not only in technical publications, but also in the newspapers and popular periodicals, the general implication of the latter being that a completely new and revolutionary field of metal-working endeavor has been uncovered. Actually, however, instead of something new, we are dealing with an art that had its inception at the time man first started using metals; numerous examples exist today of the early attempts to produce solid articles from metal powders. It is not surprising that early investigators and workers dealt with powders rather than massive structures of metals. With the exception of a few low melting metals such as tin and lead, most of the metals available melted at temperatures above those attained at the time with crude furnace equipment.

It was possible, however, to prepare powders of many metals by rather simple means without extensive furnace equipment, and a number of such powders were produced. Iron, for example, was reduced from its ores and worked to solid form at least 5,000 years ago, long before furnaces were devised which could even approach the melting point of the metal. The resulting reduced product was not, of course, massive iron, but was a sponge powder material which could be compacted, heated, sintered, and forged in much the same manner that metal powders are treated today. An outstanding example of the massive pieces produced by such methods is the 6-½ ton Delhi pillar made about 1,600 years ago.[2]

History of the Field's Development

The ancient Egyptians and probably other early civilizations discovered how to make powders of gold, silver, copper, bronze, iron, lead, and to a limited extent, tin, antimony, and platinum,[3] but it was necessity rather than desire which led these early workers to produce their massive metal tools, ornaments, and weapons by powder methods. It is interesting to note that as furnaces were devised to obtain higher temperatures, the list of metals prepared from powders decreased. The lower melting metals, of course, were the first to be prepared by melting and casting methods, and as higher temperatures were attained, only the more highly refractory metals remained on the powder preparation list.

Although iron had been known in prehistoric days, it remained a scarce, precious metal for several thousand years, and did not come into general use until introduced by the Hittites around 1300 B.C. The Hittites presumably mined iron ore in the iron region along the Black Sea in Asia Minor and worked the material to metal form.[4] By 100 B.C., the use of iron had spread westward to include many of the countries bordering the Aegean and the Mediterranean. The primitive methods of iron working probably consisted in heating the iron ore in a charcoal fire fanned by an air blast from a bellows until reduction of the oxide was attained. The spongy mass was then pressed, heated, and forged to the desired shape.

That this was the general practice followed in many countries in the production of metal objects has been observed from articles unearthed from earlier civilizations. Somewhat similar methods of working other metals have been observed, and where difficulty was experienced in obtaining sintering, other metal powders were added that were lower melting themselves, or that formed lower melting alloys which wet and welded together the particles of metal being worked to form a lump that could be shaped. The Incas in South America used such a method in fabricating many small articles of platinum.[5] The grains of native platinum were mixed with some gold and silver, and by means of a blow-pipe, were fritted together by the lower melting alloy of gold and silver. The resulting mass could then be forged to the desired shape.

During the eighteenth century there was a fair amount of activity in the production of metal powders, and in studies of the fabrication of metal parts from the powders. Platinum was introduced into England in 1741 and attempts were made to produce the metal in compact usable form.[3] Various expedients were used, and one which utilized a unique principle is worthy of note.

It was observed about the middle of the century that platinum would fuse at relatively low temperatures in the presence of arsenic,[3] and that on prolonged heating, the arsenic could be volatilized out of the fused lump to leave behind a sponge of metallic platinum. This sponge could then be heated and forged to solid form. Similar results were obtained using mercury or sulphur in place of arsenic; the success of the forging methods led other investigators to study the welding of grains of native platinum or platinum scraps without the use of added elements to lower the fusion point.

(As an example of how new methods introduced can often be traced back to earlier sources, the use of mercury to form an amalgam which could then be heated to leave a powder sponge material, has been attributed to the monk Theophilus in the 11th century.[6] In this case, the amalgam process was used with gold, and the end product sought was gold powder which could be used as a pigment in inks for illuminating manuscripts. There was no attempt, however, to carry the process further to make solid metal parts as was the case with platinum as cited above.)

Such was the situation in the early part of the nineteenth century when Wollaston[7] developed his method for the preparation of platinum ware. Numerous other investigators[3, 6, 8] had produced articles of platinum by treatment of finely divided platinum or sponge, but by careful refinements in the process with control of particle size, purity, compacting pressure and sintering treatment, Wollaston obtained a superior product. Precautions were taken to use only the more finely divided platinum particles, and to press the powder carefully in a mold while wet. This pressing of wet powder is claimed to have been one of the main contributions made by Wollaston since a much lower compacting pressure was allowable, and the particles were not work hardened.

The resulting cake was then slowly dried to remove volatile matter and adsorbed gases before sintering at 800 to 1000 C. (1475 to 1830 F.). The material was forged while still hot, and gave the first really pure, blister-free platinum sheet. That the process developed by Wollaston was sound is shown by the fact that the platinum produced by powder metallurgy at present in England is made by essentially the same procedure.[21] The careful studies made by Wollaston in fabricating platinum ware of high purity thus led to the basic principles utilized in successfully producing massive metal parts from metal powder.

During the nineteenth century, many metals were produced in powder form, but there seems to have been no correlated effort to convert the powders into coherent form. This may have been due to the development of better melting furnace equipment that allowed ordinary melting and casting techniques to be employed for most metals and alloys. On the other hand, there remained some of the more refractory metals such as tungsten, tantalum, molybdenum, osmium, and iridium which could have been treated in much the same manner as in Wollaston's process for platinum.

There were, however, instances where real effort was made to develop useful products by means of powder metallurgy. As early as 1870, the fundamental idea of a self-lubricating bearing was disclosed in a patent by Gwynn[9] and was the prototype for a large number of later developments in the field. To 99 parts of tin prepared by

rasping or filing, one part of petroleum-still residue was added, and the mass heated and intimately mixed. The mixture was then pressed to give the shape and solidity desired. It was specifically stated by Gwynn that journal boxes made by this method or lined with the material would allow shafts to run at high speed without other lubrication.[10]

There were a number of metal powder producers in the nineteenth century, most of them producing flake powders, but a virtual monopoly in the field was held by Sir Henry Bessemer from about 1840 to 1885, when he retired from the business.[11] The process was a secret one and remained so for almost his entire business career, and the profits were so large that they financed the development of the Bessemer process for making steel.

Essentially, the method used by Bessemer was one of machining very fine filaments from solid metal bars and passing the filaments through rolls to flatten and break them into flat tabular particles. Precautions were taken to prevent sticking and give a high polish to the powder by adding a very small amount of olive oil. The powder was graded by means of an air blast in a tunnel about 40 feet long and 2½ feet wide, the finest powder fraction being collected in silk bags attached to the end of the tunnel. Bessemer's powder metals included copper and most of the common alloys of copper.

Even with the relatively large scale production of flake metal powders by Bessemer up to 1885, and the subsequent preparation of powder metals by stamp mills which pulverized the metal by severe working, there was very little actual commercial manufacture of solid compacts from powder metals.

The electric lamp industry provided the stimulus for further study in the search for a metallic filament to replace the carbon filament first used. This culminated in the production of the tungsten filament, [10, 12] and indicated the technique to be applied in the development of the other refractory metals as well as the production of cemented carbides, electrical contacts, and electrode materials.

Even with the promise shown by this development and the production of other ductile heavy metals, there was little other commercial activity in powder metallurgy as late as 1915-1920.

Various types of porous bearings had received sporadic attention, and in 1921, a new porous bronze bearing was described.[13] The material was a bronze having finely divided graphite uniformly distributed throughout the mass. It was prepared by mixing the oxides of tin and copper with graphite, compressing the mass and heating. There was reduction of the oxides by the graphite and partial diffusion of the copper and tin to give a porous bronze structure in which excess graphite was uniformly distributed in amounts as high as 40 per cent by volume. In addition, there was sufficient porosity for the introduction of 2 to 3 per cent of oil. Later developments utilized the metal powders rather than the oxides,[14] and porous bearings in a variety of compositions and forms have constituted a large part of the total production of powder metallurgy products over the years.

Of considerable influence on the design and utilization of this type of bearing has been the demand by the automotive industry for large quantities of small bearing parts. Many of these parts are at inaccessible places, and the value of a self-lubricating surface is apparent. As suggested previously, these bearings are not all of the simple pressed porous alloy structure described, but many are complicated such as those having a steel backing coated with a porous sponge alloy of copper-nickel in which the voids are impregnated with Babbitt metal.[16]

A later development, and one which has had tremendous industrial significance, was the production of cemented carbides[17, 18, 19] and their use in cutting tools, dies, and hard surfaced parts of many types. Essentially these consist of finely divided tungsten carbide particles bonded by cobalt, or in some few instances, nickel or iron. Other carbides such as those of tantalum, titanium, or columbium may be added to impart special properties.

Powder metallurgy is admittedly an art that has progressed more rapidly than the science, but the gap is being closed by investigations of a fundamental nature. Much of the lack of correlated information in the field has been due, in part, to an understandable reluctance of the manufacturers to divulge information on their processes to competitors, and largely, as well, to the narrow specialized uses that apparently discouraged a general systematic investigation of the problems involved. Within the past ten or fifteen years, mainly through the efforts of producers of metal powders, research of a fundamental nature has been stimulated.

Another factor has been the large scale adoption of the powder metallurgy process by the automobile industry and by ordnance manufacturers for use in the preparation of many different parts. The field is still narrow and specialized, but the art has progressed to the point where powder metal parts are competing, in some instances, with parts made by the standard melting, casting, and machining procedures.

As in many similar situations where rapid expansion has occurred, there has been a tendency, not as yet based on actual performance, to oversell the product. This is a sign of healthy activity on the part of the exploiters in the field, but a somewhat unwise course for the industry as a whole to pursue. That there are limitations to powder metallurgy and many serious problems unsolved, is now recognized, and there is a tendency toward more conservative evaluation of its potentialities.

It is the purpose of the remainder of this article to describe some of the common methods of preparing metal powders, to explain the fundamental principles involved in powder metallurgy, to describe the advantages and limitations of the process, and to indicate the type of product that may be expected.

How Metal Powders Are Made

Metal powders are made in a variety of ways, each method of preparation being suited to the metal being treated or to the end product desired. Experience has shown that no one type of metal powder can serve all the projected uses in industry, so it is not surprising that there have been developed numerous methods for the preparation of metal powders, each of which has advantages for certain types of work, and which may or may not be suited for other uses.[11, 16]

Listed below are some of the common methods which have been developed for producing metals and alloys in powder form. No attempt is made here to discuss these methods in detail or to point out the relative hazards[20] involved in the various processes. It is worthy of note, however, that many metal powders in a finely divided state have such a large surface area in proportion to their bulk that they are usually subject to rapid oxidation, so rapid in many instances that they constitute an explosion hazard. Care must therefore be exercised throughout in the preparation of these powders, and many must be prepared and stored in inert atmospheres.

Machining

Machining of metals to produce powder has been mentioned above in connection with the process of Bessemer. A relatively coarse powder is produced. The cost of production is usually high, and the powder use is limited to a few special applications such as dental alloys where no fines or dust are allowable, and where the high cost of the alloy itself justifies the extra cost of this method.

Milling

By the use of various types of mills such as stamp mills, jaw crushers, gyratory crushers, impact, and ball mills, both brittle and malleable metals can be reduced to powder. The friable metals tend to produce angular, jagged particles of irregular shape while the malleable metals usually produce flakes. Because of the lubricant necessary with malleable metals to prevent the flakes from welding together, this type of powder is not greatly used for molding metal parts. The grease or other lubricant interferes with proper sintering, and there is an additional disadvantage of flakes in that low strength laminated or layered structures result in the pressing operation. The flake powders are more generally used as pigments in the paint industry where their flat surface is an asset for good coverage.

A special type of mill, the Eddy Mill, can be used for malleable metals to give particles of suitable shape, fineness, and purity for the manufacture of sintered briquettes. Essentially, the mill consists of a chamber wherein are mounted two fans facing one another and operating at high speeds in opposite directions. The metal is introduced into the chamber in small pieces (*e.g.* ¼-½ in. lengths of 0.05 in. diam. wire), which by collision with one another in the fan blasts, become finely pulverized. The process can be accurately controlled and a variety of shapes produced as desired.

Shotting

Metal shot can be prepared by dropping the molten metal from a small opening through air or an inert atmosphere into water. If the method is controlled properly, a fairly fine shot can be produced. On the whole, however, this process in powder metallurgical work is confined largely to preparing intermediate size particles for further reduction by other methods.

Atomization

For metals having relatively low melting points, atomization provides a convenient method of producing fine particles. The molten metal is forced through a small nozzle orifice and broken up by a stream of compressed air, steam, or inert gas. The process can be controlled rather closely by proper choice of nozzle, pressure and temperature of the gas used, and the rate of metal flow. As a rule, it is applied to metals melting below 700 C. (1300 F.) such as lead, lead alloys, zinc, and aluminum, but copper, having a much higher melting point, has also been successfully treated in this manner. The product can be drawn off and collected in standard dust collector systems, and is suitable for many types of powder compacting.

Carbonyl Process

Both nickel and iron under suitable temperature and pressure conditions will react with carbon monoxide to form the respective carbonyls.[22] From these carbonyls, the metals can be obtained by a reverse of the process, decomposing the compound to the metal and the monoxide. The virtue of the process lies in the shape of particles, which appears to be almost spherical, the purity, and the control which can be exercised in particle size. The method has been used for years in the Mond process for making nickel shot, but until recently, foreign producers exercised almost a complete monopoly on the manufacture of fine powders from carbonyl.

Within the last few years, iron carbonyl powder has been produced on a large scale in this country in several different grades suited to industrial needs. The iron powder is a specialty product commanding a higher price than that produced by most other methods, but because of superior properties, it has been used extensively in the electrical industry, particularly in the communications field for various types of magnetic cores.

Condensation of Vapor

Metals which have low boiling points can be vaporized and the vapor then condensed in powder form, including zinc, magnesium, and cadmium. These powders are used mainly in the chemical industry.

Reduction of Chemical Compounds

Metal powders whose characteristics can be varied over a wide range are prepared in large quantities by reduction of compounds of the metal with hydrogen or other reducing gases at temperatures below the melting point. The oxide of the metal is most generally utilized for the purpose, and among the metals produced are copper, nickel, iron, cobalt, molybdenum, and tungsten. The type and shape of the metal powder is governed somewhat by the compound from which it is reduced, so that within limits, these factors are controllable by proper choice of compound.

Electrolytic Deposition

Metals can be electrodeposited in several ways to obtain powder depending upon the plating conditions. A hard, brittle deposit may be obtained which can be further crushed or ground to small particles, or a soft sponge, or even the metal in powder form can be produced. The powder is usually dendritic in shape and requires further treatment for use in molding. This generally comprises milling or grinding operation, and an annealing treatment to eliminate hydrogen and soften the powder.

The Hydride Process and Other Methods

Other methods for the preparation of metal powders include chemical precipitation; granulation; alloy formation and removal of an alloying constituent (such as platinum-arsenic, platinum-mercury, and gold-sulphur previously discussed); and the hydride process.[68] The last mentioned method is probably the only one of these which is of more than academic interest for powder metallurgy uses.

Hydrides can be formed of many metals, those of titanium, zirconium, thorium, hafnium, columbium, and tantalum being of particular interest since they are reported to be stable at room temperature. They are produced in 300 mesh size or finer, have the appearance of metal, and begin to dissociate into hydrogen and the pure metal in vacuum or non-oxidizing atmospheres above 350 C. (660 F.). The hydrides can be mixed with other metal powders, and when compacted and sintered, slowly release hydrogen which creates a protective atmosphere around the metal particles and sometimes acts to remove oxide films already present.

Despite the number of methods known for producing metal powders, the bulk of the powders used on a large scale are produced by only three methods,[23] electrolytic deposition, atomization, and reduction of metal oxides or salts by gases. The carbonyl process produces a specialty product as does the hydride process, and while both have their uses, the amounts consumed are still small in relation to that prepared by the other methods.

Powder Metallurgy Processing Operations

As has been indicated in the introduction, there are a number of definite steps in the powder metallurgy process, which may be summarized as follows:

1. Selection of the powder or powders best suited for production of the part under consideration.
2. Proper mixing or blending (if more than one type of powder is being used).
3. Pressing (sometimes followed by presintering).
4. Sintering (sometimes followed by an impregnating operation).
5. Coining or sizing operation if necessary.

Each of these important operations is discussed in detail below:

Selection of Powder

When the actual metal or alloy composition has been decided upon, there are a number of factors which must be considered in the selection of the type of powder itself. An essential characteristic is purity[28] because in the powder metallurgy process impurities cannot be slagged off as in most melting processes, and may interfere with pressing and sintering operations. Oxide films, for example, may prevent good contact between metal particles. Clean surfaces are essential if ductility, and high tensile and shear strength are required in the finished article. In most cases, there is a definite limit set for objectionable impurities in a given powder, but in some instances materials normally classed as impurities are deliberately added to obtain a desired result. An example is the addition of thorium dioxide to tungsten as later described in the section on types of metal powder products.

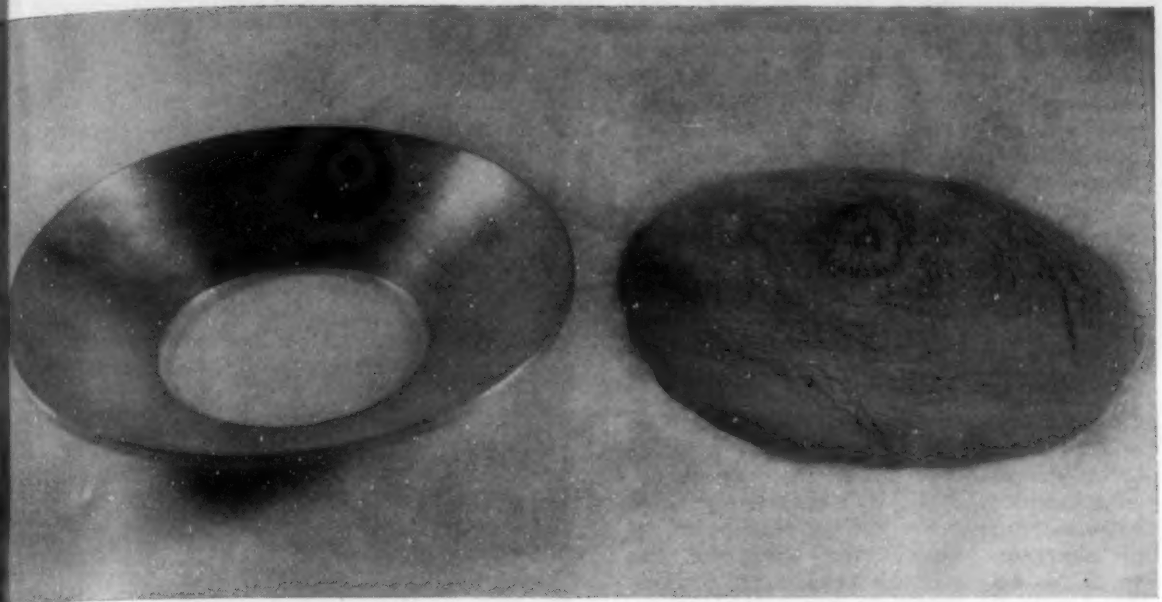
The physical properties of the metal powders are also determining factors in their selection. These include particle shape, size, hardness, particle size distribution, flow characteristics, apparent density of loose powder, and particle grain structure.

Particle shape and size is governed largely, by the method of production of the powder as has been suggested previously. The carbonyl process yields spherical particles, for example, while other methods produce particles that are angular, acicular, spongy, flat, rounded, granular, dendritic or otherwise irregular.

The hardness depends largely upon the metal itself, its purity, and the method of preparation. Hardness, in addition to shape of the particle, will be reflected in the amount of pressure required to obtain a given density in a finished part, and is a factor in the economics of die cost because of its influence on die life.

Particle size distribution in a metal powder is of great importance although no particular specification can be set up at present. The problem of size distribution and shape has been treated in some detail by W. D. Jones[24] and others, especially as concerned with interstitial volume or porosity. If all particles were cubes of the same size and could be placed in perfect order with the cube faces matching identically, there would be a minimum of porosity in the powder and in the pressed part. This is obviously impossible of attainment. In practice, packing is not systematic, but random, and even if identically sized cubes could be obtained, the voids between particles would be appreciable.

In addition to the porosity resulting from the random packing, there are cavities which are due to bridging action of the particles themselves. This bridging is not due to irregular or angular particle shape, but can occur quite easily with spherical particles. Shaking or compressing the powder tends to destroy the bridges or arches and allow denser packing. As the powder is shaken



A bronze munitions part, on the left, and a pile of metal powder from which it is made to close tolerances in a matter of seconds, as compared with 90 minutes production time for conventional methods. (This and the next 5 illustrations of powder metallurgy processes were furnished by Chrysler Corporation's Amplex Div.)

down there is rotation of particles until corresponding surfaces come in contact and relatively dense packing is obtained. Such a rotation may not be present, however, during the rapid stroke in a die, and the particles cannot seek corresponding surfaces. In this case, there is a deformation of the particles pressed against one another so that there may be an actual keying, and the smaller particles may be pressed into the voids to produce the same result of denser packing. With a distribution of particle size, the voids between larger particles can be filled with smaller particles and, in practice, that is what is sought.

The problem of setting up specified sizes or particle size distribution for powder metallurgy methods is not easy, however, because of practical complications arising in the pressing and sintering operations. Pore size rather than total porosity then becomes the problem, since, in sintering, only the smaller pores may become closed. At present, the manufacturer of metal powders cannot guarantee his particle size distribution, nor can the user determine and specify exactly what he needs. The grades can be approximated, only, and the types required must be determined in an empirical manner.[23]

The apparent density (or loading weight) is the ratio of weight in grams to volume in cubic centimeters of powder, measured according to some specified method of filling a designated receptacle. It is of considerable practical importance since it has effect on several of the operations of powder metallurgy, especially that of pressing the compact. The lower the apparent density of a powder as compared with the actual density of the solid metal, the greater will be the volume of powder required to produce a briquette of given size. This necessitates deeper dies and longer plungers than for denser materials, and for very low apparent densities, may become a serious design problem.

Powders can usually be supplied in a range of densities, and the proper powder selected for use. For proper blending and mixing of different metal powders for producing solid metal parts, it is advisable to select grades having comparable apparent densities. An example of the use of low density copper powder may be cited: For the manufacture of starting brushes in the electrical industry, copper powder and carbon powder are mixed together and compressed. By using copper powder of a low apparent density, approaching that of the carbon (1.2), good blending is assured and the danger of segregation eliminated.[23]

Low rate of flow of metal powders interferes with automatic pressing operations and may make it necessary to install vibrating equipment on the feeder hopper or even on the die itself. Rate of flow is influenced by particle size distribution, particle shape, and amount of absorbed moisture.

Mixing or Blending

When only one metal is to be pressed and sintered, there is usually no necessity for mixing since the powder as received from the manufacturer is generally well blended. Where several batches of the same metal of different particle size distribution are to be added, or where different metal powders are to be used, it is necessary to mix them thoroughly prior to pressing and sintering. This may be done in any of the standard type mixers or blenders with the precaution, in some instances, of providing against oxidation of the powders.

Pressing

For preparation of the compacts, the pressing operation may be done at either ordinary or elevated temperatures. The majority of parts produced, however, are pressed at room temperature. The presses[25, 26] which now are designed primarily for this type of work may be of the mechanical or hydraulic types for high production rates with modifications for rapid plunger strokes as required.

The dies are generally of hardened steel having the inner surfaces highly polished by lapping with polishing rouge in the direction of the plunger stroke so that any fine scratches that remain are in the direction of ejection of the pressed part.[26] In some instances where parts are made from highly abrasive particles, the dies are made of or lined with hard carbide materials. Die depth depends upon the apparent density of the powder being pressed, but the usual ratio of depth to part thickness is approximately 3 to 1. The greater die depth required for powders of lower density introduces the complications of friction at the die sides, unevenness of pressure distribution, and internal friction of the powder itself. There is almost no lateral flow in the powder mass, a condition which limits the shapes that can be pressed.

Pressure used varies from 5 to over 100 tons per square inch, in general, and is an important factor in limiting the size of parts made by the powder process.

Following pressing, a powder compact may sometimes be given a pre-sintering treatment below the normal sintering temperature in order to increase its strength to facilitate handling, or to remove lubricants or binders which might cause difficulties later.

Sintering

Sintering[24, 27, 28] is the fundamental process in powder metallurgy whereby solid bodies are bonded by atomic forces.

Theoretically it is possible to obtain bonding by bringing the powder particles into so close contact with one another that the atomic forces of cohesion may become operative. But this occurs only when the respective atoms of such adjacent particles are distant in the order of magnitude of the crystal interatomic spacings, a condition against which there are many obstructions.

Visually and even microscopically smooth particles have surfaces which are extremely jagged with respect to interatomic spacings and crystal planes. Then not large, flat areas representing large numbers of atoms, but only successive points representing relatively very small groups of atoms can be brought into sufficiently intimate contact. Moreover, even this small contact may be reduced by the presence of oxide films.

An increase of pressure will improve the bonding of such powders since the particles are deformed and pressed against one another to give increased surface contact. At the same time, rupture of the oxide films may occur with subsequent closer contact of the metal particles. This is the general case for pressed powder compacts, or "green compacts" as they are designated. There is frequently a surprising strength associated with such pressed parts, but on the whole, a heat treatment is necessary to produce a material approaching the strength and solidity of a cast or wrought metal part.

The heating of pressed powder briquettes is usually done in an inert, reducing, or neutral atmosphere, or in vacuum. The temperature used is determined by the metal powders comprising the compact, and by the properties desired in the final product. The melting point is not exceeded for any of the components of the mixture except in those instances where such fusion of a minor constituent is desired, as, for example, in the production of cemented carbides. No definite temperature may be set for the heat treatment, but general practice is to treat at a temperature about two-thirds that of the melting point of the metal or alloy being fabricated. Higher temperatures are frequently used, however, and may be only slightly below the melting point.

The effect of heat is possibly that of causing increased surface diffusion and plasticity. The atoms on the surface of metal particles possess considerable mobility far below the melting point, and the surface energy at elevated temperatures may be appreciable. Where particles are in contact surrounding a void, flow of metal is in such a direction as to increase the area of contact.

Preparing a "mix" of metal powders for blending in a mixing or blending machine.

When the sintering temperature is within the recrystallization range of the metal or metal alloy powder being treated, marked structural changes may occur. Recrystallization takes place at sites of plastic strain. Since these sites are regions of contact between particles, new crystallites form and grow into the adjacent particles so that a new series of grain boundaries is formed. The numerous cavities or voids present in the structure are not completely filled in or sealed in this operation.

This could not occur without change of overall dimensions of the compressed mass. The voids may be present at the new boundaries or even enclosed in the crystallites, and produce a non-homogeneous sintered metal of relatively weak structure susceptible to sudden shock. By a high temperature treatment just below the melting point, or by alternate working and annealing, the voids can be closed and the metal consolidated to a dense, strong mass.

Surface oxide films which interfere with the sintering operation may sometimes be destroyed by treatment of the powder compact in a reducing atmosphere. If the oxide cannot be reduced in this manner, the pure metal can only be obtained by sintering operations if the oxide has a higher vapor pressure than the metal.[29]

Gases, either adsorbed, dissolved, entrapped, chemically bound, or resulting from chemical action, may interfere with sintering and the general rule is to avoid them if possible in attempting to produce solid metal.

Following sintering, there is sometimes a treatment for impregnating a porous structure with some material designed to confer special properties to the compact. Pressed and sintered bearings may, for example, be impregnated with oil, and a strong, porous network of tungsten may be impregnated with copper by suitable means to produce spot and seam welding electrode material having high compressive strength associated with good heat and electrical conductivity.

Coining or Sizing

Although the dimensional tolerances of sintered metal parts can be rather closely controlled, it may be advantageous to control final size and improve surface structure by a coining operation consisting in repressing the compact in a die of suitable size.

Products and Applications

Most of the developments and uses of metal powders described thus far, it should be noted, have been concerned with products which could not be produced in any other way than by powder metallurgy processes. This, in fact, has been the principal field of powder metallurgy. Porous bearings with uniformly distributed porosity could not possibly be fabricated by any of the standard melting and casting techniques, nor could the carbide cutting tools be likewise manufactured.

Reasons for Use

In general, the powder metallurgy process has been applied for the purposes outlined below:[30, 31, 32]

1. Production of refractory metals such as tungsten, tantalum, columbium, and molybdenum.
2. Development of structures not practical by other methods. These include not only articles requiring uniform or controlled porosity such as porous bearings and metallic filters, but products like telephone and radio cores as well.
3. Preparation of metals to include uniformly distributed non-metals.
4. Preparation of samples comprising a metal with another metal or metals which would be immiscible in the molten state, or which do not form alloys, e.g. tungsten-copper contacts and electrodes.
5. Preparation of samples of two or more metals where one component has a low boiling point.
6. Fabrication of products that can be made more economically by the powder process than by other methods.[14]

Considerable work has been done by the automotive industry and others in developing products from powder metals that fall into class 6 above. There are many instances where automatic pressing and continuous annealing operations on small parts in quantity have made the process economically feasible for competition with the standard casting method. There are many factors involved in determining whether parts should be thus fabricated, and these will be described at greater length in the section on limitations of the powder method.

With the advent of increased production for war purposes, the powder process has, in many instances, been utilized to insure a steady supply of many small parts needed for ordnance. The use of powder metallurgy has released machines and mechanics for other types of work, and because of the speed and ease of setting up for production, it has often been possible for suppliers of small parts to adhere to schedules they could not otherwise meet.[33] In addition, because of the low metal loss connected with the powder process, there is considerable saving of scarce or strategic material.

To the six general classes of applications listed above, can then be added another class that can best be described as utilitarian. The powder method has been used as an expedient to supplement and extend normal production methods without regard to cost. However, it has often proved itself to be economically competitive, and in many cases, has effected considerable savings over normal production methods.[33]

The intensified war production schedules have opened the larger field that has been long predicted by powder metallurgists, that of using the powder method to displace the conventional methods of making many parts not in the classification of specialty products. Even under the abnormal war conditions, however, there are indications that progress along these lines will not be rapid and the early promise shown has not been completely realized. Progress has been made, nevertheless, but many of the developments and products are known only to those workers actually engaged in producing parts for the wartime program, and only when the story of the progress made can be told, will complete evaluation of the process be possible.

It is the belief of some engineers and metallurgists, as yet realized commercially with only a few special items, that parts can eventually be prepared by powder methods with properties superior to those obtained by melting, casting, and working techniques. At least one investigator reasoned that since sintered tungsten is stronger than fused tungsten, iron or steel prepared similarly should show the same superiority.[34] Actual studies conducted using relatively high compacting pressures indicate that both iron and steel can be prepared by powder methods with tensile properties better than those obtained on the same materials made by fusion processes.

Typical Products

Most of the materials produced by powder metallurgy prior to about 1940 are well known; some have already been mentioned in this article, but for convenience are included in the following descriptions of typical products. Others of more recent development owe their immediate existence to the demands of wartime production, and while some have been described in some detail in the technical literature, many have had only brief mention. Some typical parts made by powder methods are shown in the accompanying illustrations.

Cemented Carbides[17, 18, 19, 35]

Although tungsten carbide was produced many years ago and was found to be extremely hard, it was so brittle and low in strength that its use commercially where advantage could be taken of the high degree of hardness was not possible. About 20 years ago, it was discovered that the addition of a small amount of metallic constituent, such as cobalt, to the tungsten carbide

The blended powders are pressed to shape at pressures normally up to 50 tons per sq. in. (sometimes higher). The powder is fed to the die through the tube at the left, the part is pressed, and the pressed part is ejected from the die (as shown here)—all automatically.

powder would yield a hard, relatively strong compact after sintering. During the heating operation, there is partial melting with some solution of the carbide by the cobalt; and on cooling, the cementing material produces the required strength.

The method of preparing the powders, compacting, and sintering has undergone considerable improvement since the first carbide materials were made. Essentially, in outline, the process consists of first preparing the tungsten carbide powder, mixing it with cobalt powder and ball milling the mixture until proper grain size is obtained and the carbide particles are coated with a thin layer of the cementing metal. In this treatment, other carbides are added as required. Following the milling operation, the mixed powders are pressed in suitable molds and given a pre-sintering heat treatment to increase the strength for handling and to remove, by volatilization, lubricants which may have been used to facilitate pressing.

After the pre-sintering operation, the compact can be cut to desired shapes quite readily. The sintering treatment which follows is carried out at about 1400-1500 C. (2550-2750 F.) with the pressed parts placed in carbon boats or on carbon slabs and heated in a suitable neutral or reducing atmosphere. There is considerable shrinkage in dimensions in this sintering treatment which gives a product that is hard, dense, sound, and strong. Any further shaping is done by grinding or lapping operations.

The cemented carbides have many uses usually falling into the three general classes of die materials, cutting tool materials, and wear and corrosion resistant materials.

The die materials are usually the simpler tungsten carbide compositions and can be used to advantage for extruding, drawing, sizing, and other operations where the shape or dimensions of the article being worked is changed but where no metal is removed in the operation. The tungsten carbide can be used in this way for shaping many types of metals and alloys and this has been a major use of the product.

Cemented carbides, either the simple type or the mixtures, depending on the application, have been successfully used as cutting tips on a variety of tools, and for a number of different materials. This use has increased steadily due to the remarkable increase in production achieved. Decrease in cost of the tips and parts during recent years has further stimulated use.

Wear and corrosion resistant parts include gages, guides of many types, pump valves for abrasive materials, sandblast nozzles, burnishing tools and dies, and many others where utilization of the superior properties is indicated.

One use recently reported[36] has been that of cemented tungsten carbide for bullet cores in ammunition for anti-tank weapons used by the enemy in the desert warfare in Africa. The material has about twice the density of steel and is much harder, and although not greatly resistant to shock under normal conditions, becomes quite effective under the high pressures attained during striking and penetrating armor plate.

Porous Bearings

Porous bearings, always a large runner in the powder metallurgy field, have been described in the section on the historical development. Where the bearings are impregnated with oil, there is usually sufficient oil to last the lifetime of the assembly, but provision can readily be made for supplying additional oil if needed by utilizing the capillary action of the interconnecting pores to draw oil from a reservoir in contact with the bearing wall. In such assemblies, there is always a film of oil for the shaft to run on in contrast to normal bearings where an oil film does not coat the shaft until run for some time.

Motor Brushes and Commutator Segments

Numerous types of current collector brushes are now made by powder methods. Copper powder can be added to the graphite mixture, the desired part pressed and sintered below the melting point of copper to develop a strong, high conductivity brush of longer life for use against copper surfaces. Greater wear resistance may be obtained by adding zinc, tin, or nickel to the mixture. Improvement in operating smoothness may be attained by the incorporation of lead.[14, 28]

The brushes can be pressed around pigtail conductor wire inserts to insure good contact for the lead wire and eliminate attachment problems.

Commutator segments, resistance rings, and rotor bars in squirrel-cage motors, have been successfully produced from copper by powder metallurgy methods.[37]

Refractory Metals

Because of high melting points, the refractory metals, of which tungsten, molybdenum and tantalum are the most important, are prepared by powder methods. The preparation of each is similar, with the technique differing only in certain details where the characteristics of the individual metals require it.[38]

With tungsten,[39] the ore is treated by chemical methods to yield pure tungstic oxide which is then reduced by hydrogen at 650-950 C. (1200-1750 F.) to give tungsten powder with a particle size range from 0.5 to 8 microns. As with other metal powders, care is exercised throughout to maintain high purity. After proper mixing and blending, the powder is compressed and the briquette given a pre-sintering treatment at 1000-1200 C. (1800-2200 F.) to give sufficient strength for further handling.

The resulting bar is then clamped in electrodes in a suitably designed hydrogen chamber, where acting as a resistance heater, heavy electric current is passed through it. The compact shrinks, the density increases,

Small pressed metal-powder parts are here being placed on a continuous conveyor belt before entering the heat-treating or sintering furnace, in which the "green," relatively weak briquette is strengthened by consolidation and bonding.

and a relatively solid bar results which can then be hot worked. During the swaging or rolling, the working temperature can be gradually decreased until there is sufficient ductility by control of grain size to draw the material cold.

For tungsten used in lamp filaments, certain additions such as thorium oxide, or compounds of sodium or potassium mixed with such relatively non-volatile materials as silica, alumina or thoria are intimately mixed with the tungstic oxide prior to reduction. These additions are effective in controlling grain growth and insuring proper grain boundary orientation for producing "non-sag" coiled filament.

Essentially, the sodium and potassium compounds promote large grain growth while the others such as thorium oxide inhibit grain growth under the conditions of wire fabrication. When the material is drawn in wire form, the thoria particles form elongated stringers in the direction of drawing and tend to prevent grain growth across the wire while allowing exaggerated growth along the axis of the wire. The resulting structure of long grains with boundaries forming acute angles with the longitudinal axis of the wire is ideally suited for the coil type of lamp filament.

Molybdenum and tantalum are prepared in much the same manner as tungsten, although tantalum sintering and annealing must be conducted in high vacuum because of the ability of the metal to absorb and retain gases at high temperatures.

Heavy Alloy

"Heavy alloy" is the name applied to a group of alloys composed of tungsten, copper, and nickel having a density of 16 grams per cc. or greater.[40, 41] They were originally developed for fabricating the containers and nozzles for radium units, but have such interesting properties that a number of other uses have become evident. Specific properties depend upon the composition, but generally the tungsten comprises about 90 per cent of the alloy.

One of the best compositions is that of 90 tungsten—7.5 nickel—2.5 copper which has properties as listed below:

Tensile strength	90,000 p.s.i.
Yield point	83,000 p.s.i.
Elongation in 1 inch	4%
Modulus of elasticity	32×10^6 p.s.i.
Brinell hardness	250-290
Density	16.3-17.0 gms. per cc.
Coefficient of expansion	5.6×10^{-6}
Thermal conductivity	0.25 c.g.s. units

The alloys are prepared by mixing the metal powders dry, adding a small amount of wax, in benzol solution, mixing until the solvent has evaporated, and then pressing to shape. The compact is heated slowly to about 1000 C. (1800 F.) and then sintered at a higher temperature at which the nickel and copper particles fuse, and the tungsten is not only wet by the liquid, but actually dissolved. The fine particles are thus dissolved, but tungsten is reprecipitated on certain nuclei to develop large rounded grains. The solution and redeposition continue until the original fine tungsten particles are replaced by grains approximately 100 times the original particle diameter. The alloy thus consists of tungsten particles in a cementing phase of copper-nickel-tungsten.

There is a shrinkage of up to 20 per cent, and the resulting compact is free of porosity. The alloy has good machining properties and can be treated much like many cast alloys. It has good corrosion resistance and can take a variety of surface finishes.

In addition to its use in X-ray and radium work, its high density and strength make it attractive for use as a counterweight material in high speed motor setups of many types.

Electrical Contacts and Electrode Materials

Powder metallurgy can be utilized to fabricate material composed of two or more metals without any appreciable alloying so that the characteristics of each of the components may be retained to a large degree. This has opened a large field for electrical contacts and welding electrodes made by using compositions where the refractory nature of materials such as tungsten, molybdenum, nickel, or graphite can be retained, while good electrical conductivity may be obtained with copper and silver.[14, 32, 43]

Another type of material with good spark quenching properties is the combination of silver and cadmium oxide, which, because no alloying results, also has high electrical conductivity.[43]

The contact materials may be made by any of the suitable powder techniques. One method is to press and sinter the powder composition sought, with or without final sizing or shaping of the part. Another method that is utilized for making tungsten-copper compositions consists in pressing a bar from tungsten powder and sintering at 1300 C. (2370 F.) in hydrogen. The tungsten thus forms a strong porous structure which can then be impregnated with copper. This may be accomplished by placing the part in a graphite boat with copper, heating above the melting point of the latter, and allowing the voids to be filled by capillary action.[44]

No single contact material is satisfactory for all purposes, and a number of different combinations have been developed. These include silver-tungsten, copper-tungsten, silver-graphite, silver-molybdenum, cemented tungsten carbide, and copper-nickel-tungsten. They are used in many installations such as circuit breakers, welding machines, relays, and many types of industrial control equipment.

Alnico Magnets

Many Alnico magnets of small size have been produced commercially by powder methods.[45, 46] Magnets made in this manner are fine grained in contrast to the relatively coarse grained material obtained by casting methods. The material is uniform throughout with no cold shuts, cracks, blow holes or grain boundary segregation so that a more uniform flux density is obtained. Of particular interest are the close dimensional tolerances which can be maintained in the powder method and the small amount of grinding required in finishing. The composition can be held much more closely than for the cast alloy.

The process is limited economically to the production of small samples. Large samples can be prepared by conventional methods at a cost that would not allow sintered products to compete.

The presence of a highly oxidizable element (9-13 per cent of aluminum) presented difficulties when attempts were first made to prepare Alnico by sintering pressed compacts. To overcome this oxidation, the aluminum is added in the form of alloy powder of 50 aluminum-50 iron composition prepared by crushing and ball milling a casting of the brittle material.[47] In such form, there is practically no oxidation of the aluminum under the sintering conditions which prevail.

Another method to minimize or eliminate oxidation in sintering operations utilizes, in addition to the 50 aluminum-50 iron powder, approximately 2 per cent of titanium hydride incorporated in a powder mixture of aluminum-iron-nickel.[48] Decomposition of the hydride commences at about 450 C. (850 F.) with release of nascent hydrogen so that during the sintering operation, oxidation is prevented and part or all of any oxide already present may be reduced. (The need for titanium hydride in the preparation of alloys of this type, and the effect of the hydride in controlling oxidation has been the subject of some discussion.[48] Its use is mentioned here only as a variation of the method described above and apart from any effects it may have on the magnetic properties of the alloys to which it is added.)

Metal Filters and Screens

Related to the porous metal type of bearing and prepared in much the same way are the metal filters and screens made by powder methods.[8, 49] Bronze, copper-nickel alloys, or pure nickel may be utilized, and porosities up to 80% by volume may be obtained. These filters have been used to advantage in the chemical industry for filtering strong alkaline solutions, and other liquids of many kinds. One reported application is as a fuel filter 5 inches long and 2 inches in diameter for a Diesel engine.[8]

Generally, the filter part can be bonded to steel or copper and made an integral part of the apparatus in which it is to function.

In the manufacture of the filters, the porosity can be accurately controlled. In addition to the methods of producing porous parts as previously described, a highly porous metallic mass can be prepared by sintering the component metal powders (sometimes with volatile additions) in the uncompacted condition using a protective atmosphere and a temperature determined by the type of powders used.[50]

Alloys Requiring Close Composition-Control

There are some alloys for special purposes where accurate control of composition and reproducibility of composition are of primary importance. Two such materials are low expansion alloys for metal to glass seals, and thermocouple wire for temperature measurement.

An alloy of 54 Fe, 28 Ni and 18% Co having approximately the same coefficient of expansion as certain grades of glass is normally prepared by melting and casting procedures. This alloy can be prepared by sintering methods, however, with the same physical characteristics, but with closer composition control and less contamination.[44]

Alloys of nickel-molybdenum and nickel-tungsten have been prepared by powder methods for use as thermocouple elements.[44] When these are used with nickel wire as the second element, the couples can operate at temperatures up to 1300 C. (2400 F.) for nickel-molybdenum and 1400 C. (2550 F.) for nickel-tungsten. Ease of preparation and not reproducibility of composition was probably the main factor in the fabrication of these two types of thermocouple elements since the compositions reported are in the range where relatively large changes in composition produce little variation in thermoelectric voltage.

Porous bearings are here shown being removed from the oil-impregnation bath often used to give permanently built-in lubrication.

Parts for Ordnance

As has already been mentioned, many powder metal parts are being manufactured for use in equipment of the Armed Services, and while in some instances, the parts are made by powder methods only because of expedience, it should be noted that in all cases, definite specifications must be met before acceptance, and a powder metal part that does not meet the rigid requirements has no more chance of acceptance than has an inferior part made by other methods.

Among the parts which have been successfully produced are copper and brass rotating bands for projectiles.[50] While the cost of the powder metal bands is greater than that of bands made in the normal manner from copper or brass tubing, they compare favorably in actual performance in firing tests both as to behavior on the projectile and wear on the gun barrel.

Improvement of the strength of porous metal bearings has been a factor in their adoption for use in anti-aircraft guns where they may operate under severe conditions. It has been reported that 100 parts are thus utilized in a single gun installation.[51]

Another item reported to be in production is an iron powder part of an elevating hand mechanism for both the .30 and .50 caliber anti-aircraft machine guns.[38] Knurling of the outer surface of the ring part and the marking off of degrees are performed on the part in a coining blow.

Sintered Iron Parts

Prior to the wartime demands for sintered iron parts, there had been developed a fairly extensive field for peacetime uses particularly in the automotive industry. Bearings had been manufactured for some time, and following this, production had extended to the fabrication of oil pump gears, door catches, cams, and other parts where very high strength is not essential. In general, these sintered iron parts have mechanical properties similar to those of cast iron, but considerable range in properties may be obtained by proper selection of raw material and treatment. Grading of parts from iron powder into three classes according to the type of product and properties has been outlined as follows:[52, 53]

- *Type A:* Materials having mechanical properties similar to ordinary cast iron suitable for applications where stresses are very low.
- *Type B:* Materials similar to Type A but having improved tensile strength, a definite yield point, and a noticeable elongation.
- *Type C:* Materials having mechanical properties approaching ordinary malleable iron, suitable for applications where stresses, including impact, are moderate.

Prior to 1941, the iron powder used commercially for pressed and sintered parts was of Swedish origin because that was the only powder available in quantity, quality, and at a price which allowed competition economically with established methods of production. Domestic iron powders are now available, however, that are superior to those formerly imported.

Of the sintered iron products manufactured in this country, an interesting example is a small gear for automobile oil pumps.[27] This gear was formerly made by machining cast iron blanks but was adapted for powder metal production because of greater ease in fabrication at less cost and more satisfactory operation. The gear teeth must be true involute curves with surfaces such that noisy operation and binding are prevented. All of these characteristics can be readily obtained by pressing and sintering, while more difficulty is encountered with cast gears because of the intricate machining work involved. The sintered gear avoids these expensive machining operations, and the teeth have so much better surface finish, and mesh so accurately, that noisy operation is avoided. In addition, the associated porosity is helpful in that oil impregnation assists in smoother and quieter operation.

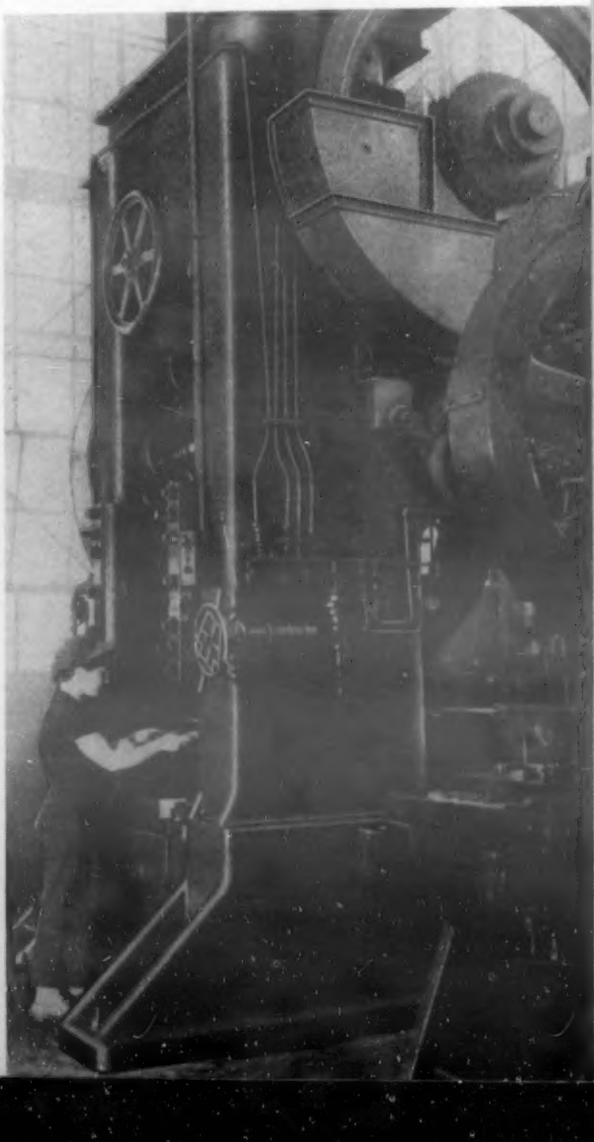
The pressed gears are lighter in weight than the cast gears, and while the mechanical properties are not of high order, they are satisfactory for the use.

Cladding and Duplexing

Powder methods are useful in cladding, duplexing, or any of the processes whereby one metal or alloy may be coated with another for protective purposes, to obtain special properties as in bimetal strip, to obtain hard surface layers on strong, tough backing material, or to obtain a thin layer of relatively high cost metal of desirable properties on a suitable low cost backing strip.

For fabrication of bimetal, layers of the respective component metal powders may be placed in the die in the desired proportions and compacted. Upon sintering, an alloy bond is formed between the layers, and the briquette may be rolled or otherwise worked to the desired thickness.[50, 54] An advantage of this type of bimetal fabrication is the use of alloy bonding at the interface instead

Presses also perform the sizing or coining operation, which is the final step in the powder metallurgy process, eliminating any distortion from sintering and providing final dimensional accuracy of ±0.0005 in. if required.



of a solder which might limit the operating temperature of the material.[14]

Metallic Friction Materials[14, 55]

The ordinary type of friction material for brake linings, clutch facings, and similar uses is generally composed of asbestos with an organic type of binder. Under normal operating conditions, this type of material is quite satisfactory, but where severe conditions of operation are encountered, the heat generated at the braking surfaces may be sufficient to decompose the binder and cause rapid wearing of the friction facing.

By powder methods, however, a metallic matrix can be formed with admixtures of friction producing ingredients to give a facing that is capable of withstanding the high temperatures generated under severe operating conditions. The exact composition of the facing is determined by the requirements, and a number of different metallic and nonmetallic materials are used. Generally, however, the basic ingredient of the matrix is copper to which may be added such modifying metals as tin, lead, zinc or iron. The friction producing powder is generally an abrasive such as silica or emery which is varied in amount according to the coefficient of friction that is desired.

The metallic elements may constitute only about 50 per cent of the part by volume with the other 50 per cent represented by nonmetallic ingredients and pores. Consequently, the facing is weak and brittle and usually bonded to a strong backing plate.

The friction materials are prepared in the normal manner by mixing suitable powders, compressing in suitable form (usually as thin annular rings), and sintering. The sintering operation is generally performed so that the part is bonded to the backing plate at the same time. Finishing operations are then performed to adjust the facing to size and proper shape for use.

Cores for Inductance Coils for Telephone and Radio[56, 57]

Although the manufacture of cores for induction coils for telephone and radio use does not fit into the field of powder metallurgy as more strictly defined in the Introduction, the procedure is in many ways so similar to the processes described above, and the product of such interest, that a brief description is included in this review.

The coils in communication circuits may operate over a wide range of frequencies from voice frequencies up to millions of cycles per second. By the use of a finely divided magnetic powder, the particles of which are insulated from one another, the eddy current losses in the cores can be reduced to a level low enough for satisfactory use.

The first metal powder used for cores in the telephone industry was electrolytic iron. This was later superseded by more suitable magnetic materials such as the permalloys.

The procedure utilized to obtain the permalloy powder is worthy of note. Ingots of the desired composition are prepared by melting and casting in the normal manner with, however, the addition to the melt of a small amount of sulphur which acts as an embrittling agent to facilitate pulverization. The sulphur exists as microscopic films of complex sulphides at the crystallite boundaries. At normal temperatures, these films are brittle, but at elevated temperatures, are either malleable or dissolve in the iron-nickel solid solution.

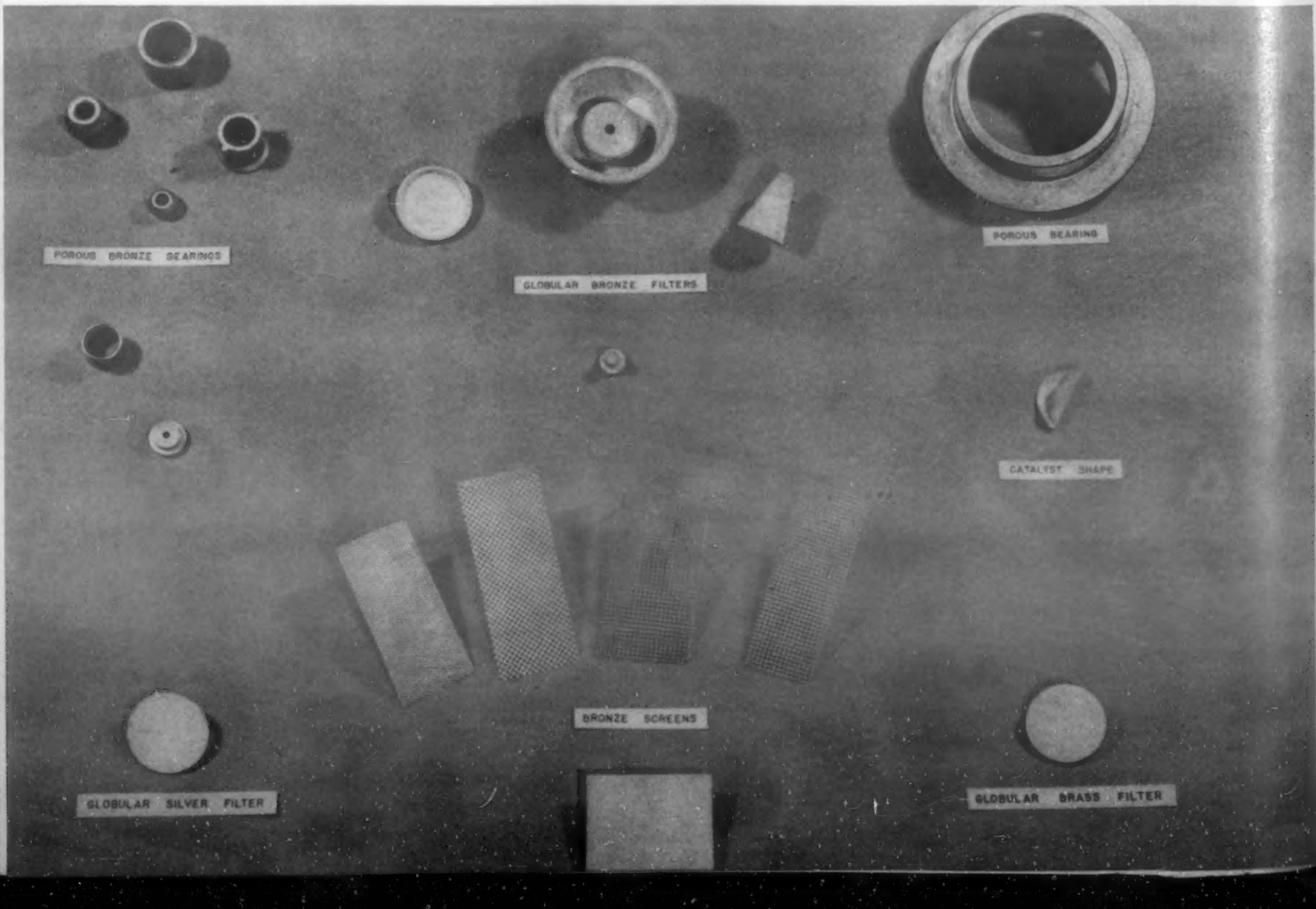
The alloy can therefore be hot rolled to small section under controlled conditions to develop a desired grain size, and then cold worked to separate the individual crystals. Grain size depends upon the degree of refinement in the hot rolling operation, and upon the distribution of the sulphide film around the grain boundaries. Final pulverization is accomplished in an attrition mill, and the product is generally annealed to soften the particles.

The powder is then treated to cover each of the particles with an insulating film that is generally of the ceramic type. The cores are then pressed at about 100 tons per square inch to develop proper density and strength. There is no sintering treatment performed on this type of material after pressing, but the cores are generally annealed to remove pressing strains and restore magnetic quality.

This powder metal process is thus different from those previously described and is also one of the specialty group of materials which cannot be prepared by any other methods. Except for the deliberate coating of the metal particles with an insulating film, and the avoidance of a sintering operation, however, the procedure is that normally followed in preparing powder metal articles.

In addition to the permalloys described, a number of other magnetic powders are used in pressed core form for various applications. These include electrolytic iron, carbonyl iron, and several types of magnetic oxides. Carbonyl iron, in particular, has been used extensively for radio cores where the spherical shape and small size of the particles have been factors in their successful utilization.

Some typical porous parts for which the powder metallurgy method of manufacture produces their essential voids or controlled porosity. (This photo and the following two pictures of parts were provided by Hardy Metallurgical Co.)



MATERIALS & METHODS MANUAL 2

Advantages and Limitations

Throughout this article, numerous advantages of the powder metallurgy process have been indicated as well as some of the limitations. Outlined below in somewhat more detail are these considerations and others which enter into an evaluation of the process as a whole. In those instances where a product cannot be made in any way except by powder methods, evaluation is easy. But for those products which must compete with standard methods of fabrication, the problem is more complex, and generalizations cannot always be applied. The competitive position of powder metallurgy as a fabricating method, with respect to many of the design and production factors in which the engineer is interested, has recently been set forth in some detail.

Advantages

The following are some of the advantages of the powder metallurgy process:

1. High purity of the metal content of the finished product can be maintained. Control of the manufacture of the powders enables producers to supply metals that generally run well above 99 per cent purity, and often as high as 99.99 per cent for some metals such as tungsten, tantalum, and zirconium.[28] Opportunity for additional impurity pickup is slight under the conditions prevailing in the pressing and sintering operations, so that the original metal purity is retained, and may even be improved by oxide reduction or removal of volatile impurities.

2. Composition of the product can be accurately controlled and reproduced.[30, 44] There are no losses due to oxidation or slagging as in melting processes so that the metal content can be quite readily fixed.

3. Structures, alloys, or materials not possible of fabrication by any other method can be produced by powder methods.[29, 30, 49, 58] These have been adequately described and include porous bearings, sintered carbides, refractory metals such as tungsten and tantalum, and combinations of metals, and of metals and non-metals that do not alloy.

4. High production rates,[58, 61, 65] especially on small parts, can be attained by use of automatic presses of the pill tabletting type and of continuous type sintering furnaces. One order of forty million small parts required by the Navy was produced at the rate of 520 pieces per minute by powder methods.[64]

Larger size articles cannot be produced at any such rate because of press limitations which may necessitate hand operation, but with pressed iron parts, high rate of production is one of the factors that allows the process to compete with other standard methods of manufacture.

5. A wide range of certain physical properties can be obtained for any particular material being fabricated.[58, 62] Control can be exercised over such properties as density, porosity, grain size, and strength by variation of the type and size of powder particles, die pressure, and sintering time and temperature.

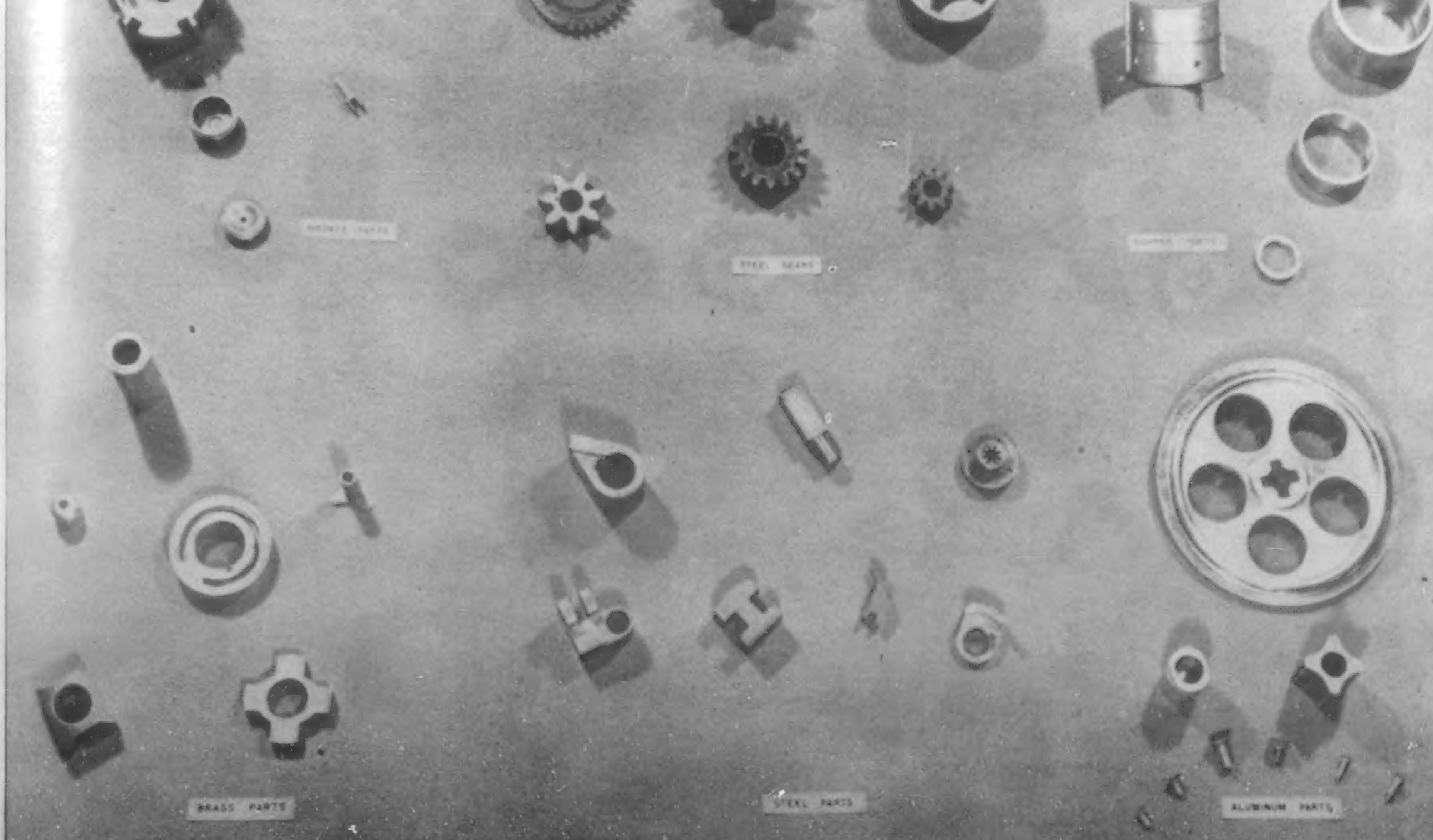
In some instances such as small Alnico magnets, structures developed may have better mechanical properties than the same material in cast form.[44, 45, 46, 47] The same type of fine grain structure developed in laboratory samples of iron parts compacted at high pressures and sintered at relatively low temperatures also exhibit superior tensile properties.[34]

6. The powder method of manufacture may be more economical in many instances due to factors such as rapid quantity production, lower labor costs, ease of setting up for manufacture, conservation of material, and elimination of machining operations.[30, 62] A reported instance of analysis of the normal cost of producing approximately one hundred different units used in a piece of Ordnance equipment revealed that powder metal parts effected a saving of about 70 per cent.[33]

7. Rather close dimensional tolerances[30, 58, 61] on small or medium size parts up to about 2 inches major dimension can be secured, averaging ± 0.001 in. Closer tolerances of ± 0.0005 in. are attainable and may be even smaller on special production jobs. On larger parts, the tolerance may be in the order of ± 0.002 in. Frequently, however, accuracy of dimensions is attained only through a coining or re-pressing operation of the sintered part.

8. There is usually very little material waste associated with powder metal parts manufacture since there is little or no scrap loss.[28, 58, 62] Powder losses generally run

Some machine parts made by powder metallurgy.



below 0.5 per cent.[59] In melting and casting operations on small parts, on the other hand, the sprues and risers may be several times the weight of the finished casting. In addition, machining operations on cast parts may remove from 10 to 50 per cent of the metal, and while most of it is recoverable as scrap, it represents a loss in the manufacturing process.[62]

9. Highly skilled labor is not required for most operations in the powder method.[33, 59] Except for the construction of the necessary dies and die parts, semi-skilled labor may be used. This is of value in industrial plants producing parts for Ordnance because skilled mechanics who would normally be required for machining operations can be made available for other work.

10. Tooling costs are relatively low in comparison with other high production methods, and less time is usually required to set up for production.[33] Secondary operations such as machining of the sintered products may be eliminated or greatly reduced.

Limitations and Design Factors

As has been indicated in several sections of this review, there has been a recent shift in emphasis in the type of product made by powder methods, and in addition to those materials that are difficult or impossible to make by other methods, parts are now being manufactured in direct competition with those made by conventional, established procedures.

Under these circumstances, economy of production, in addition to technical feasibility, becomes a major factor in the utilization of the process. Of the numerous limitations of the process, some are inherent and definitely limit its application while others are incidental and susceptible to certain measures of control. The more important of these limitations and problems are outlined below:

1. The cost of metal powders is high in comparison with metal for other methods of producing similar parts, and availability of suitable powders is another problem.[44, 63] Both cost reduction and availability have received considerable attention in recent years, and with increased use of metal powders and the large scale powder production entailed, substantial price reductions have been effected and a wider variety of types of powder have been made available. The development of domestic sources of supply of a satisfactory low cost iron powder to replace Swedish sponge iron is an example of a successful attempt to overcome a limitation of the process.[58]

In a final analysis, metal powder costs must be balanced against overall costs before a raw material cost standard can be set up.

2. Die expense[14, 44, 61, 63] is high, especially for large and complicated parts and for high pressures. New dies are required for each part of different shape and size, and each die must be installed and carefully adjusted for operation. With the entry of powder metallurgy in the low cost part field, there will be need for more complicated dies to meet the competition of intricately shaped parts produced by casting methods. The tool cost, however, for the powder process is generally lower for a given part than with other processes. Die cost may range from about $150 for small simple parts up to $1800 or more for large parts or complicated shapes.[33]

3. Sintering furnaces pose many problems in the production of powder metal parts.[14] Close temperature control and uniformity are essential for control of dimensional changes in compacts. The fabrication of iron or alloy steel parts requiring higher temperatures than have been previously utilized in the industry add to the difficulties of furnace design.

4. The size and form of powder metal products is limited.[44, 62, 63] Large samples require huge presses to obtain the desired compacting pressures and both tool and press costs increase. Increase in size of compacts leads to a non-uniform distribution of pressure and may adversely affect the shape and dimensions of the article in the sintering operation. Large presses are usually not of the automatic type, which means hand operation with lower production rates and increased cost. Low apparent density of most metal powders affects die design and limits the thickness of parts produced. A compression ratio of about 3 to 1 is generally assumed which means mold depth must be at least 3 times the thickness of the finished compact. Other factors of die design are noted under item 7 of this section.

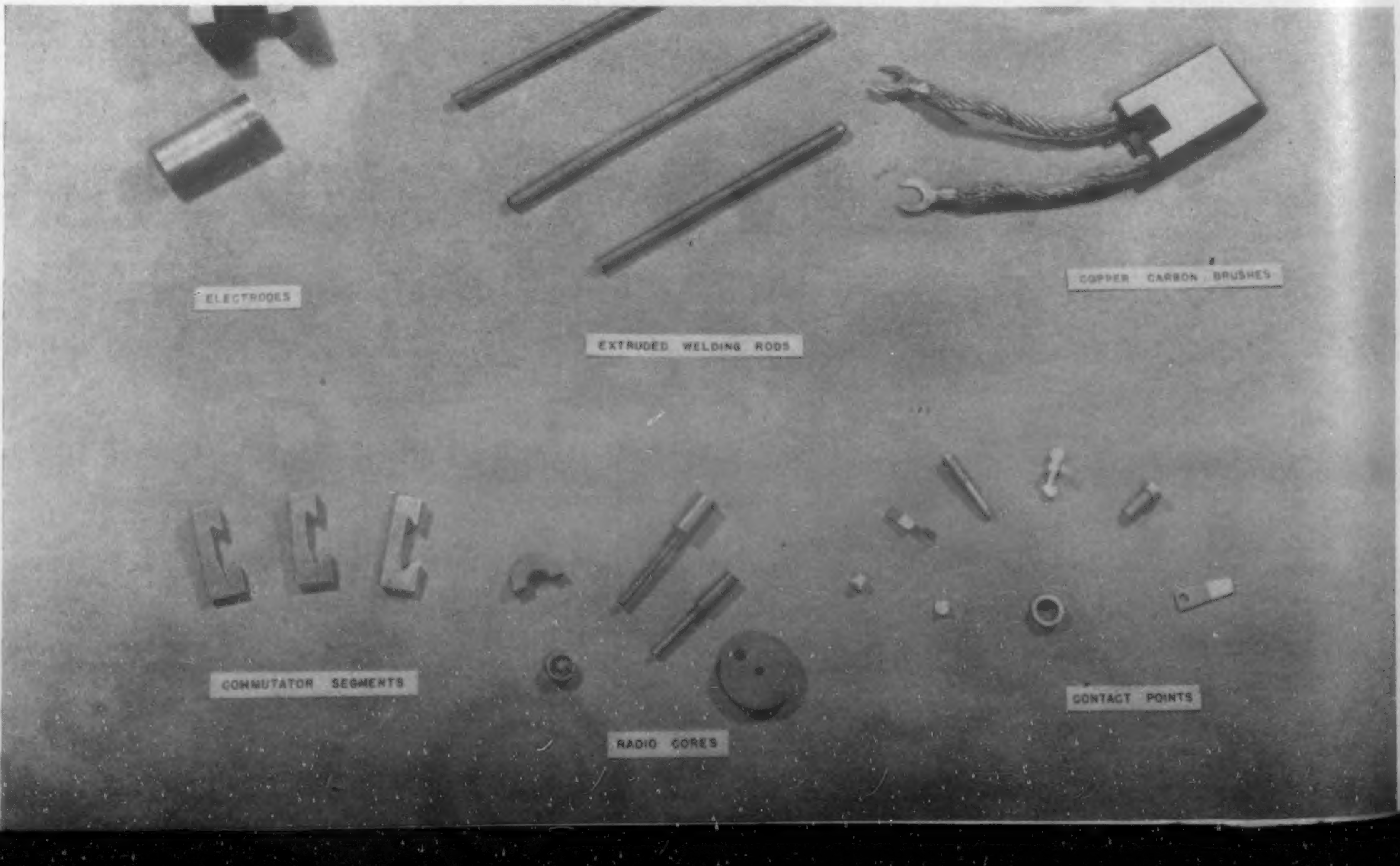
5. The powder process is essentially one of mass production, and a reasonable number of parts must, in general, be fabricated or the costs per unit will be excessive.

6. On a production basis, powder metal structural parts generally have relatively low elongation, tensile strength and impact strength.[14, 44, 63] The mechanical properties of a sintered part depend to some extent on its density, which itself is a function of the type of powder used, the compacting pressure, and the sintering treatment. Because of the voids normally present in powder metal parts, the ultimate properties cannot be expected to be as good as those obtained on cast and wrought materials.[62]

7. There are a number of design limitations for powder metallurgy parts.[11, 44, 61, 62]

a. Sharp corners should be avoided and internal angles should have fillets.
b. Large and abrupt changes in thickness of parts should be avoided, as should uneven cross sections.
c. Re-entrant angles, grooves, and undercuts cannot be molded, and if required, must be machined in an extra operation. Internal and external threads, and holes at right angles to the central hole or perpendicular to the axis of pressing, likewise cannot be pressed, and must be machined.
d. Length of pressed parts must be comparable to the cross section area because of pressing limita-

Familiar electrical parts whose manufacture from metal powders is well established.



tions. A long section may have a soft central portion of low density.

e. There is almost no flow of metal powders during compacting because of friction between particles, and between particles and the die walls.[60, 62]

8. Although powder parts can be produced to close dimensions by careful control of the compacting and sintering operations and by coining or re-pressing the sintered pieces, tolerances should, in general, be fairly liberal if costs are to be kept down.[14, 61] Close dimensional tolerances may necessitate machining operations to meet specifications. Eccentricity of cylindrical parts may be controlled fairly closely, but concentricity may be troublesome because there must be clearance between die parts and plungers, and the clearances may be cumulative.[60]

9. There is a lack of technical information available for engineers and designers. Tests on metal powders and finished parts have not been standardized, and until such standardization has been achieved, the metal powder consumer and the ultimate user of the sintered parts have no check on the respective products. This situation is now being remedied.

10. There are some thermal limitations that may cause difficulties in the sintering process in certain instances.[63] Some oxides can be reduced only at temperatures above the melting point of the metal itself, and prevent effective welding of the powder particles.

11. Metal powders in a fine state of subdivision are readily combustible and must be treated as potential fire and explosion hazards.[20, 62] Zirconium, magnesium, aluminum, and titanium are the most inflammable with iron, manganese, zinc, silicon, tin, and antimony, moderately inflammable. Precautions must be taken to keep dust out of the air in the mixing and pressing rooms, not only because of the explosion hazard, but also because of possible toxic effect on workers.

12. Deterioration of metal powders may occur in storage due to oxidation or absorption of moisture with subsequent chemical reaction to change the composition.[62]

Conclusion

This correlated review of some of the more common aspects of powder metallurgy is presented to provide information on an increasingly important production method. The review makes no pretense of complete coverage of the subject, and many important topics such as hot pressing, press and furnace design and operation, sintering atmospheres, and die design and operation have not been described. These and other more specialized topics that are beyond the scope of this paper may be found in the appended list of references.

Acknowledgment

The authors have drawn freely from many of the articles on powder metallurgy published during the past 10 years. Wherever possible, reference is made to the original source of the topic material or to associated articles where more complete information may be found. To these sources listed below, the authors are indebted for much of the material in this review.

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MATERIALS & METHODS MANUAL 2

An Appendix by the Editors

These four tables—the first of their kind ever published for this field—are intended to serve as a general guide to product types and sources of supply for powders, powder metallurgy parts and processing equipment. Specific data about individual products should be obtained from their manufacturers. Company "nicknames" used in the data columns in Tables I and III are identified in the list of manufacturers in each case.

I. METAL POWDERS AND THEIR SUPPLIERS

Material	How Produced	Purity or Composition	Available Meshes	*Typical Applications	Suppliers of Specific Powders
Aluminum	Atomized	99.0+%	–10 to –325	5, 17, 24, 29	Hardy, MD, Reynolds
	Flake-Milled	——	–325	7, 22, 24	Alcoa, MD
Aluminum Alloy	Atomized	96-98%	–100	17, 29	Hardy, Reynolds
	Hot Milled	Dural	–60 to –300	26	Unexcelled
Antimony	Milled	99%	–100 to –325	5, 20, 29	Hardy, MD
Beryllium	Reduced	97+%	–200	20	Hardy
Beryllium Alloys	Milled	2.5% Be-Cu	–60 to –300	9, 17	Unexcelled
	Hydride	10% Be-Ni	–100	17, 20	Hydrides
Bismuth	Milled	99.9%	–200	20, 29	Hardy, MD
Brass	Atomized	60/40 to 90/10	–100 to –325	1, 2, 3, 4, 12, 17	Hardy, MD, N J Zinc
	Atomized	60/40	–30	12	N J Zinc
	Atomized	70/30	–100 (Spher)	11	N J Zinc
Bronze	Flake-Milled	Cu-Zn-Al	various, to –325	7, 22	Am Bronze
	Reduced	——	various	1, 12, 17	MD
	Hot Milled	77 Cu, 8 Sn, 15 Pb	–60 to –300	1, 12, 17	Unexcelled
Cadmium	Milled	99.5%	–100, –300	1, 20, 29	Hardy
	Atomized	——	–325	1, 20, 29	MD
Chromium	Milled	98+%	–150 to –325	9, 10, 20, 21, 28	Hardy, MD
Cobalt	Reduced	97.5-99%	–100 to –300	10, 13, 19, 28	Hardy
	Reduced	99.9%	–325	10, 13, 19, 28	R & R
Columbium	Reduced	95.0+%	–50	10, 16	Fansteel
Copper	Electrolytic	99.5+%	–100 to –325	1, 3, 4, 5, 8, 11, 12, 15, 17	A M Co, Gen Met, Hardy, MR
	Reduced	99.5+%	–40 to –325	1, 3, 4, 5, 12, 17	MD, PM & A
	Atomized	——	–30 to –200	11	N J Zinc
	Flake-Milled	——	–325	4, 7, 22	Am Bronze
Copper-Nickel	Hot-Milled	70 Cu, 30 Ni	–60 to –300	9	Unexcelled
Graphite	——	97-98% C	–200, –325	4	Dixon
	——	95+% C	–325	1	Dixon
	——	90-92% C	–200	12	Dixon
	——	95, 97% C	5 micron	——	Dixon
	——		–200 & finer	1, 4, 12	National Carbon
Iron	Reduced	99+%	many, to –325	1, 5, 9, 13, 17, 18, 23	MD, PM & A, Hardy
	Reduced	97-98.2%	–8 to –325	1, 5, 9, 17, 23	MR, Plast Met
	Electrolytic	99.5%	–8 to –325	1, 17, 18, 19, 23	Plast Met, E & T
	Carbonyl	98-99.9%	–180, –400	1, 18, 23	G A W
Lead	Atomized	99.5-99.9%	–100 to –325	1, 3, 5, 14, 22	A M Co, Hardy, MD, MR
Magnesium	Milled	96-99.9%	–15 to –325	24	Apex, Magna, NS, Nat Mag, NE Mag
Manganese	Milled	99.9%	–100 to –325	17, 20, 29	Hardy, MD
	Electrolytic	99.75%	–20 to –325	17, 20, 29	Plast Met
Molybdenum	Reduced	99.90%	–150, –200, –300	8, 10, 16, 28	Callite, Hardy
	H-Reduced	99.7+%	–80	8, 10, 16, 28	Fansteel, NAP
	Reduced	99+%	–80	8, 10, 16, 28	Hardy
Nickel	Milled	Ni+Co 99%	–150 to –325	9, 10, 13, 19, 21	Hardy, MD
	Flake-Milled	——	–325	7, 22	Am Bronze
	Reduced	99.5%	various	various	P M & A
Nickel-Copper	Hot Milled	70 Ni, 30 Cu	–60 to –300	9	Unexcelled
"Nickel Silver"	Hot Milled	Cu-Ni-Zn	–60 to –300	9	Unexcelled
Silicon	Milled	96, 97+%	–100 to –325	12, 17, 19, 20	MD, Plast Met, Hardy
Silver	Electrolytic	99.90%	–200 to –325	4, 8	A M Co, H & H, Hardy, MD
	Flake-Milled		–325	7	Am Bronze
Solder	Atomized	50/50; 40/60	–40 to –325	1, 3, 29	MD
Stainless Steel	Corrosion	18/8	–60 to –300	9, 11, 26	Unexcelled
	Milled & Reduced	35/15	–60 to –300	9, 11, 26	Unexcelled
Steel	Reduced	97-99% Fe	various	1, 17	P M & A
Tantalum	Electrolytic	99.8+%	80% –400	9, 10, 16	Fansteel
Tantalum Carbide	——	Ta C	–200	28	Fansteel
Thorium	Reduced	95+%	–100	20	Hardy
Tin	Atomized	99.5+%	–40 to –325	1, 12, 17	MD, MR, Hardy
	Flake-Milled	——	–325	7, 22	Am Bronze
Titanium	Reduced	99.5%	–250	13, 20	Hardy
	Hydride	98-99.5%	–100	13, 20	Hydrides
Ti Hydride	Hydride	98-99.5%	–325	20	Hydrides
Tungsten	Reduced	99.9+%	–150, 200, 300	8, 10, 16, 28	Callite, Hardy, R & R, Fansteel, NAP
	Reduced	99.0	–80 to –300	6, 8, 16, 25, 28	Callite, Hardy
Tungsten Carbide	——	WC	various	28	Carboloy, Fansteel
Vanadium	Milled	90%	–80 & finer	20, 28, 29	Hardy
Zinc	Atomized	99+%	–24 to –325	5, 17, 21, 29	M D, Hardy, N J Zinc
Zirconium	Reduced	99.5%	–250	10, 16, 20	Hardy
Zr Hydride	Hydride	99-99.9%	–200	10, 16, 20	Hydrides

General List of Powder Suppliers

- (Alcoa) Aluminum Co. of America, Pittsburgh
- Aluminum Bronze Powder Co., Bedford, O.
- (Am Bronze) American Bronze Div., Metals Disintegrating Co., Verona, N. J.
- (A M Co) American Metal Co., Ltd., New York
- (Apex) Apex Smelting Co., Chicago
- Baer Bros., New York
- Belmont Smelting & Refining Co., Brooklyn, N. Y.
- (Callite) Callite Tungsten Corp., Union City, N. J.
- (Carboloy) Carboloy Corp., Detroit
- (Dixon) Jos. Dixon Crucible Co., Jersey City, N. J.
- (E & T) Ekstrand & Tholand, Inc., New York
- (Fansteel) Fansteel Metallurgical Corp., No. Chicago, Ill.
- (Gen Met) General Metals Powder Co., Akron, O.
- (G A W) General Aniline Works Div., New York
- Goldfield Consolidated Mines Co., San Francisco
- (H & H) Handy & Harman, New York
- (Hardy) Chas. Hardy, Inc., New York
- Harshaw Chemical Co., Cleveland
- O. Hommel Co., Pittsburgh
- (Magna) Magna Mfg. Co., Inc., New York
- McAleer Mfg. Co., Rochester, Mich.
- (Hydrides) Metal Hydrides, Inc., Beverly, Mass.
- (M D) Metals Disintegrating Co., Elizabeth, N. J.
- Metals, Incorporated, San Francisco
- (M R) Metals Refining Co., Div. of Glidden Co., Hammond, Ind.
- National Carbon Co., Cleveland
- (Nat Mag) National Magnesium Corp., New York
- (N S) National Smelting Co., New York
- (N E Mag) New England Magnesium Co., Inc., Malden, Mass.
- (N J Zinc) New Jersey Zinc Co. of Penna., Palmerton, Pa.
- (NAP) North American Phillips Co., Inc., New York
- (Plast Met) Plastic Metals, Inc., Johnstown, Pa.
- (P M & A) Powder Metals & Alloys, Inc., New York
- Pyron Corp., Niagara Falls, N. Y.
- (R & R) Reduction & Refining Co., Newark, N. J.
- (Reynolds) Reynolds Metals Co., Louisville, Ky.
- (Unexcelled) Unexcelled Mfg. Co., New York, N. Y.
- U. S. Metal Powders Co., Closter, N. J.
- U. S. Magnesium Co., Pleasant Valley, N. Y.

** The numerals in this column refer to the products or applications listed numerically in the Table on page 1341.*

II. POWDER METALLURGY APPLICATIONS, AND MANUFACTURERS OF PARTS AND PRODUCTS

Applications or Products	Materials Available	Reasons for Using the Powder Method or Parts	Manufacturers of Specific Products
1. Bearings	Iron, iron-copper, bronze, bronze-graphite, brass, brass-graphite, silver, copper-lead, copper-nickel-babbitt	Controlled porosity and integral self-lubricating feature producible only by this method. Porous bearings are economical, noiseless and long-lived	AEM, Amplex, BB, Crowley, FM, Johnson, Keystone, Mallory, Midland, Moraine, Neveroil, Rhoades, Wellman
2. Bimetallic Thermoelements	Nickel, nickel-iron alloy, brass, platinum, tungsten, etc. in special alloys and combinations	Provides firm, integral alloy bonding of bimetal layers	Callite, NAP, Wilson
3. Brazing and Soldering	Copper, phos-copper, brass, silver alloys, solders	Powders and pastes often more easily applied to work than wire or sheet	Brazing with metal powders and pastes is done in hundreds of plants
4. Brushes (Motor)	Copper-graphite, copper-alloy-graphite, silver-graphite	Duplex structure, combining high conductivity and low friction, producible in no other way	GE, Keystone, Morg, St.M, Speer, Stackpole
5. Chemical Applications	Zinc, iron, aluminum, magnesium, platinum, molybdenum, etc.	Zinc, iron, aluminum are effective reducing agents in powder form. Magnesium used in Grignard reaction, others as catalysts	Applied throughout the chemical and process industries
6. Counterweights	Tungsten, "Heavy Metal" (Cu-Ni-W), etc.	Heavy balance weights of tungsten or its alloys must be fabricated from powder because of excessively high melting point	Mallory
7. Coatings (on paper, ceramics, plastics, etc.)	Aluminum, tin, copper, silver, gold, platinum, selenium, tellurium, etc.	Powders may be dispersed in liquid vehicle, uniformly applied to the surface, and fused into it	Coatings are applied widely in the graphic and ceramic arts
8. Contacts and Electrodes	Tungsten, copper, molybdenum, silver, nickel, graphite and precious metal base materials or combination, e.g. Cu-W, Ag-W, Ag-Ni, Ag-Mo, Ag-Graphite, Ag-PbO, Ag-Ni-Graphite, Ag-Ni-W, WC-Ag, WC-Cu, Ag-CdO, etc.	Duplex structures, providing high conductivity and wear resistance of separate ingredients, producible only by powder method. Also constituents are frequently not compatible when molten	AEM, Callite, Clet, Fansteel, GE, Gibson, Gen-Tung, Keystone, Mallory, Met, NAP St.M, Sirian, Speer, Stackpole, Wilson
9. Corrosion-Resistant Parts or Claddings	Monel, chromium, tantalum, stainless steel, silver, iron-copper, tungsten, beryllium-copper	Useful for production of sintered-on protective coatings or parts that would be difficult or uneconomical to make otherwise	AEM, Callite, Fansteel, others
10. Electronic Tube Materials	Tungsten, tantalum, molybdenum, columbium (often with dispersed ingredients like thoria, sodium, etc.)	Refractory metals cannot be melted economically. Powder method guarantees high purity, or permits inclusion of dispersed oxides	Callite, CWW, Fansteel, GE, Met, NAP, Sirian
11. Filters and Screens	Iron, brass, bronze, silver, nickel-copper and special alloys	Controlled porosity producible only by powder metallurgy. Special alloys are possible. Metal filters are stronger than ceramics	AEM, Amplex, Crowley, Keystone, Midland, Moraine
12. Friction Discs, Facings, etc.	Copper-base, brass-graphite, bronze-graphite, Cu-Sn-Pb-base, copper-iron, etc.—all containing a siliceous friction ingredient	Only this method provides alloy matrix with dispersed frictional and lubricating ingredients. Better service, smaller parts than non-metals	Amplex, Gen Met, Keystone, Moraine, Wellman
13. Glass-to-Metal Seals	Iron-nickel-cobalt alloys, tungsten, molybdenum	Accurate control and reproducibility of composition; less contamination	Callite, GE, others
14. Greases	Lead, graphite and mixtures	Powders can easily be incorporated in greases	Compounded by various grease manufacturers
15. Grinding Wheels	Diamond-in-tungsten carbide, diamond-in-bronze, etc.	Only way combination of durable, wear- and heat-resisting matrix and diamond abrasive can be made	Carboloy, Norton
16. High-Melting Metals	Tungsten, tantalum, molybdenum, columbium, and their alloys	These metals have melting points too high to be economically fabricated by melting and casting	Callite CWW, Clet, Fansteel, GE, Gen Tung, Met, NAP, Sirian
17. Machine and Ordnance Parts	Iron, steel, brass, bronze, aluminum, copper, iron-copper, copper-graphite, bronze-graphite, brass-graphite, iron-graphite, etc.	More economical production of large quantities of intricate parts to close tolerances than other methods. Often cheaper than machining. Self lubricating feature possible	AEM, Amplex, BB, Crowley, Keystone, Midland, Moraine, Morg, Stackpole, others
18. Magnetic Cores	Iron or iron-nickel, plus binder and insulator	Pure, uncontaminated metal permitted by this method. Structure is magnetically ideal. Often cheaper than machining	AEM, Ferro, Mallory, Pyro, Stackpole
19. Magnets (Permanent)	Aluminum-nickel cobalt iron alloys ("Alnico"), other iron-base alloys	Fine-grain, more uniform structure, better flux distribution than cast. Small magnets cheaper by powder method because of unmachinability of material	GE, Gen Mag, Indiana, Stackpole, T & S
20. Metallurgical Alloying and Refining	Aluminum, antimony, beryllium, bismuth, cadmium, copper, chromium, maganese, silicon, thorium, titanium, various hydrides, etc.	Powders react quickly in molten metal baths, and are best way of making uncontaminated master alloys of many types	Melting plants, foundries, master-alloy manufacturers, etc.
21. Metal Spraying	Aluminum, copper, brass, tin, zinc, nickel, lead, cadmium, iron, stainless steel, special alloys, etc.	Metal powders as spray-metal provide quick melting in gun and permit mixtures of metals and with non-metals to give special coatings	Metal-spraying by the powder method is widely applied in industry
22. Paint Pigments	Aluminum, copper, zinc, brass, bronze, tin, lead, nickel, silver, gold	Flake powders provide "leafing" and brilliant metallic surfaces when paint dries. Metal paints are attractive and corrosion resistant	"Bronzing" pigments are formulated by many manufacturers
23. Pole Pieces	Iron and iron alloys	Improved electrical properties, greater design flexibility, lower cost than laminated structures	AEM, Amplex, Moraine
24. Pyrotechnics	Chiefly magnesium, aluminum and their alloys	Highly oxidizable metal powders are most effective ignition agents, incendiary bomb ingredients and light producers for flares	Army, Navy and munitions manufacturers; flash powder and fireworks companies in peacetime.
25. Radium Containers	Tungsten and "Heavy Metal" (W-Ni-Cu)	High-density material used (tungsten-base) can be fabricated only by powder method because of high melting point	
26. Seals, Retainers, Spacers, etc.	Copper-base, copper-graphite, bronze-graphite, iron, etc.	Permits mass production of intricate, hard-to-machine shapes to close tolerances. Can also be self-lubricating, non-scoring and noiseless	Amplex, Keystone, Morg, Wellman
27. Thermocouple Elements	Nickel-molybdenum, nickel-tungsten and other W or Mo combinations	Difficult to make otherwise because of high melting points. Couples are good for high temps.	GE
28. Tools, Dies and Wear-Resistant Parts	Carbides of tungsten, tantalum and titanium—alone, mixed or combined	Materials not suited to melting because of high melting points. Powder method also permits close control of purity and structure	AEM, Callite, Carboloy, Firth, Gen Air, KM, MC, NECT, TAM, Tung El, VR, Wesson, WCT

General List of Powder Metallurgy Fabricators*

(AEM) American Electro Metal Corp., Yonkers, N. Y.
(Amplex) Amplex Div., Chrysler Corp., Detroit
(BB) Bound Brook Oil-Less Bearing Co., Bound Brook, N. J.
(Callite) Callite Tungsten Co., Union City, N. J.
(Carboloy) Carboloy Co., Inc., Detroit
(Clet) Cleveland Tungsten, Inc., Cleveland
(CWW) Cleveland Wire Works, Cleveland
(Crowley) Henry L. Crowley, Inc., West Orange, N. J.
(Fansteel) Fansteel Metallurgical Corp., No. Chicago, Ill.
(FM) Federal-Mogul Corp., Detroit
(Ferro) Ferrocart Corp. of America, Hastings-on-Hudson, N. Y.
(Firth) Firth-Sterling Steel Co., McKeesport, Pa.
(Gen Air) General Aircraft Equipment Co., So. Norwalk, Conn.
(GE) General Electric Co., Schenectady, N. Y.
(Gen Mag) General Magnetic Corp., Detroit
(Gen Met) General Metals Powder Co., Akron, Ohio
(Gen Tung) General Tungsten Mfg. Co., Union City, N. J.
(Gibson) Gibson Electric Co., Pittsburgh
(Indiana) Indiana Steel Prods. Co., Chicago
(Johnson) Johnson Bronze Co., New Castle, Pa.
(KM) Kennametal, Inc., Latrobe, Pa.
(Keystone) Keystone Carbon Co., Inc., St. Marys, Pa.
(Mallory) P. R. Mallory & Co., Inc., Indianapolis, Ind.
(MC) Metal Carbides Corp., Youngstown, O.
(Met) Metroloy Co., Inc., Newark, N. J.
(Midland) Midland Die & Engraving Co., Powdered Metal Prods. Div., Chicago
(Moraine) Moraine Prods. Div., GMC, Dayton, Ohio
(Morg) Morganite Brush Co., Inc., Long Island City, N. Y.
(NECT) New England Carbide Tool Co., Cambridge, Mass.
(Neveroil) Neveroil Bearing Co., Wakefield, Mass.
(NAP) North American Phillips, Dobbs Ferry, N. Y.
(Norton) Norton Co., Worcester, Mass.
(Pomet) Powder Metallurgy Corp., Long Island City, N. Y.
(Pyro) Pyroferric Co., New York
(Rhoades) R. W. Rhoades Metaline Co., Inc., Brooklyn, N. Y.
(St. M) St. Marys Carbon Co., St. Marys, Pa.
(Sirian) Sirian Wire & Contact Co., Newark, N. J.
(T&S) Thomas & Skinner Steel Prods. Co., Indianapolis, Ind.
(Speer) Speer Carbon Co., St. Marys, Pa.
(Stackpole) Stackpole Carbon Co., St. Marys, Pa.
(TAM) Tungsten Alloy Mfg. Co., Newark, N. J.
(Tung El) Tungstein Electric Corp., Union City, N. J.
(VR) Vascoloy-Ramet Corp., No. Chicago, Ill.
(Wellman) S. K. Wellman Co., Cleveland
(Wesson) Wesson Co., Ferndale, Mich.
(WCT) Willeys Carbide Tool, Co., Detroit, Mich.
(Wilson) H. A. Wilson Co., Newark, N. J.

** In addition to the companies listed there are several (Westinghouse, Western Union, Western Electric, for example) who make powder metallurgy parts but exclusively for their own use and not for sale.*

III. POWDER METALLURGY PRESSES AND PRESS MANUFACTURERS

Operating Principle	Pressures, Speeds and Other Features: Single-Acting	Double-Acting	Other Types	Type of Work for which Well-Suited	Press Manufacturers
Hydraulic (including oil - hydraulic and oil-electric)	Production pressures run from 500 tons to 5000 tons or more, with speeds available according to pressure and part-size. A Hydropress machine for example rated at 500 tons operates at 10 cycles/min. A 35-ton lab press works at 30 in. per min.	Pressures from below 75 tons (a Kux toggle type, for example) up to 5000 tons (Bliss) are available. Stroke speed of a Kux 150-ton press is 20/min.; of a 600-ton Hydropress press, 2/min. Ram speeds of an HPM 750-ton press are 350 in./min. closing and 20 in./min. pressing.	Duplex and duplex double-acting presses reach 5000 tons pressure (Bliss). HPM has several double-action machines with horizontal and vertical rams whose pressures are 60/45 up to 1500/1000 tons and speeds 6/6 to 114/4 in./min. Hydropress's quadruple-action press is rated at 350/250 tons and 8 cycles/min.	*Single Acting:* Good for simpler shapes in various sizes; suitable for coining and sizing. *Double Acting:* General purpose presses, and for higher-pressure, more complicated jobs. Can be used for carbides, sizing, dense parts, etc. *Others:* Duplex widely used for thick shapes. Right angle actions popular for carbides and other work.	Baldwin-Southwark Div., Philadelphia; Birdsboro Steel Fdry. & Machine Co., Birdsboro, Pa.; (Bliss) E. W. Bliss Co., Brooklyn, N. Y.; Fred S. Carver Co., New York; Clearing Machine Corp., Chicago; Arthur Colton Co., Detroit; Continental Machines, Inc., Minneapolis, Minn.; Denison Engineering Co., Columbus, O.; Chas. F. Elmes Engg. Works, Chicago; A. B. Farquhar Co., Ltd., York, Pa.; Hydraulic Machy., Inc., Dearborn, Mich.; (HPM) Hydraulic Press Mfg. Co., Mt. Gilead, O.; (Hydropress) Hydropress, Inc., New York; (Kux) Kux Machine Co., Chicago; Lake Erie Engg. Corp., Buffalo, N. Y.; Schloemann Engg. Corp., Pittsburgh; (Stokes) F. J. Stokes Machine Co., Philadelphia; Watson-Stillman Co., Roselle, N. J.; R. D. Wood Co., Philadelphia; Zeh & Hahneman Co., Newark, N. J.
Mechanical (Toggle, Rotary, Straight Side, Knuckle-Joint, etc.)	Pressure ratings from 10 to 100 tons for one type of inclinable press to 25 to 1500 tons for a straight side and knuckle-joint press (both made by Bliss) Speeds are 6 to 150 strokes/min.	Pressures from 15 tons to 140 tons, and stroke speeds of 6 to 1000/min. (the last a Kux 25-ton rotary press) are available. Stokes, Kux and others have wide selection of presses of various ratings classified according to depth of die fill, from 1⅜ up to 8 in.	Typical duplex presses are rated at 100-600 tons and 4 to 30 strokes per min.	*Single Acting:* Good for general pressing of porous parts (not too complex in shape), preforming, sizing, etc. *Double Acting:* Most diversified type, used on general work, porous parts, intricate shapes, very-high-production jobs, dense parts, repressing, sizing, etc.	

IV. MANUFACTURERS OF MIXERS, BLENDERS AND GRINDING MILLS FOR METAL POWDERS

Mixers and Blenders	Grinding Mills, Disintegrators, etc.
Abbe Engineering Co., New York	Abbe Engineering Co., New York
Baker Perkins, Inc., Saginaw, Mich.	American Pulverizer & Crusher Co., St. Louis, Mo.
Franklin-McAllister Corp., Chicago	Franklin-McAllister Corp., Chicago
Hardinge Co., York, Pa.	Hardinge Co., York, Pa.
Lancaster Iron Works, Brick Machy. Div., Lancaster, Pa.	Jeffrey Mfg. Co., Columbus, O.
National Engineering Co., Chicago	Patterson Foundry & Machine Co., E. Liverpool, O.
Patterson Foundry & Machine Co., E. Liverpool, O.	H. K. Porter Co., Pittsburgh
H. K. Porter Co., Pittsburgh	Pulverizing Machinery Co., Summit, N. J.
Pulverizing Machinery Co., Summit, N. J.	Raymond Pulverizer Div., Combustion Engg. Corp., Chicago
Read Machinery Co., Inc., York, Pa.	Stedman's Foundry & Machine Works, Aurora, Ind.
Sturtevant Mill Co., Boston	Sturtevant Mill Co., Boston

NUMBER 63
November, 1944

The Forging of Aluminum Alloys

The strength possibilities of the wrought aluminum alloys are frequently utilized in structural forms, where their high strength-to-weight ratio offers an advantage. This advantage is particularly important in mobile equipment, such as aircraft, railroad rolling stock, and trucks, where the dead weight may be decreased with corresponding increase in pay load.

Wrought aluminum alloys may be worked without difficulty by hammer forging, hot pressing or upset forging. All usually make use of dies to obtain high production to close tolerances. Operations are similar to those commonly performed on steel.

It is somewhat surprising that aluminum, with its lower strength, lower melting point, and lighter weight, requires more power for forging than does steel. This is because the metal must be worked at comparatively low temperatures, at which its resistance to flow is still quite high. Some of the largest forging equipment is used for aluminum alloys. The hot working range is fixed by the plasticity of the metal for the lower limits and the "hot-shortness" of aluminum and its alloys for the upper limits. Commercial aluminum melts at about 1214 F., and becomes brittle at temperatures somewhat lower, so that aluminum is best hot-worked between about 600 F. and 900 F. For the alloys the upper limit will be about 880 F. Both tend to strain harden when worked below the lower limits.

Alloy	32S	18S	73S	14S	17S	70S	25S	A51S
Max. forging temp. F.	800	820	820	840	840	840	860	880

Alloys for Forging

The alloys which acquire their hardness through cold working are not widely used for forging, since they are annealed at forging temperatures. The heat treatable alloys can be used without such complications, but require care so that they may preserve their maximum corrosion resistance. The strain-hardened alloys are sometimes worked by heating to 300 to 400 F., at which temperatures their resistance to forming decreases somewhat while their hardness is only slightly lessened. This temperature should not be maintained for more than half an hour.

Physical properties of the aluminum alloys were given in a preceding "Engineering File Facts" [No. 24, in METALS AND ALLOYS for October 1943, pp. 813, 815]. Of the alloys that have been developed especially for forging, a few may be mentioned. Alloy 25S is one of the easiest to fabricate, and finds wide application where good strength and corrosion resistance are required. Alloy A51S is even more easily formed, and is used chiefly for large or intricate parts where ease of forming is a prime consideration. Its mechanical properties are slightly lower than those of 25S. Alloy 14S is used where high strength is required, as it is the strongest, in the heat treated condition, of the standard forging alloys.

The best known of the strong alloys, duralumin or 17S, is used where high corrosion resistance is a requirement. The alloy 53S is even more corrosion resistant. Forgings in both alloys require heat treatment to develop their maximum corrosion resistance as well as strength properties. The latter is used for architectural hardware and in the chemical industries. If the fabricating process will include welding of the forged parts, the metals 2S or 3S may be selected.

If the forged piece is to be finish machined, the alloy selected might be 11S, which can be cut easily even in the heat treated condition. Alloy 70S, which has excellent forging properties, is also used for forgings requiring good mechanical properties.

When the alloy must retain its strength characteristics at elevated temperatures, as in internal combustion engine pistons, 18S or 32S may be used. The latter is particularly suitable in that it has the lowest coefficient of thermal expansion of the standard wrought alloys.

Forging at Low Heat

In certain light forming operations with the heat treatable alloys, it is possible to work them at a temperature of about 400 F. In this way their formability is increased without the decrease in corrosion resistance that accompanies prolonged heating at higher temperatures. Wherever possible, the time of heating should be held under half an hour.

Aluminum forgings in general show excellent grain structure and soundness. Pieces produced by hot pressing have a good surface finish. Dimensions can be held so closely by this method that only a few thousandths of an inch need be allowed for machining.

For hammer forgings a set of dies is usually used. Draft of 7° should be provided to permit ready removal of the piece, although deep projections may require as much as 10° draft. Rapidly operated hammers, in which the dies are separated at a velocity almost as great as that when delivering the blow, may reduce this draft to as little as 2°.

Draft allowances for press forging are usually less than for hammer forging. A draft angle of 0.25° is usually sufficient if the shape of the forging does not provide natural draft. Upset forging dies commonly require about 1° of draft.

Tolerances

Allowances for shrinkage are based upon the linear dimensions, and the tolerance is commonly +0.004 in. and —0.002 in. per in. for small sizes.

Length or Width	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.
Shrinkage tolerance	+0.004 —0.002	+0.008 —0.004	+0.012 —0.006	+0.016 —0.008	+0.020 —0.010	+0.024 —0.012

(Continued on page 1349)

Tolerances for mismatch in the dies is usually fixed upon a weight basis, as follows:

Wt. of Forging	to 2.5 lb.	2.5 to 6.25 lb.	6.25 to 8.5 lb.	8.5 to 15 lb.	15 to 20 lb.	over 25 lb.
Mismatch tolerance	0.015 in.	0.018 in.	0.021 in.	0.024 in.	0.028 in.	0.032 in.

Calculation of these tolerances should be made in conjunction with each other, not as a sum. The effect requiring the greatest allowance in a given direction should govern for that dimension. If finish machining is required, metal allowance must be made in addition to the tolerances for shrinkage and mismatch.

Radii at fillets, flanges, corners and edges should be as large as the design will permit. Use of small fillets increases wear on the die, and makes more difficult the flow of metal into the deeper recesses of the die cavity.

Dies for forgings having wide, thin webs should have a Shore hardness of 55 to 60. For ordinary work, the hardness should be about Shore 48 to 51. Large dies, especially those having deep impressions, may do best at a Shore hardness of 45 to 48. Press dies are harder—Shore readings are usually 55 to 60, with hardness to 65 for special jobs.

Dies should be designed so that the finishing impression is as near the center of the die as possible. Equal proportioning of the amount of work to be done in the various impressions will help to lengthen die life. Ample edge distance must be kept.

It seems to be the concensus of opinion among die designers that the die impression should be so cut that the metal flow of the forging occurs at right angles to the grain direction of the die block material.

Preparing the Stock

Forging stock may be rolled or bar stock. Extruded forms may be used economically to produce a blank that will save one or more steps in the forging operations, and forgings made from such stock may show unusually high mechanical properties. However, normal forging operations permit recrystallization to occur, and properties in the heat treated part after this type of fabrication may be lower than those in the extruded blank after heat treatment. Increasing amounts of forging permit increasing recrystallization, and yield and tensile values may decrease to those obtained with as-rolled, heat treated stock.

When the form requires, rough blocking may be used to shape a blank that will fill the blocking impression in the die. Large forgings may be made from an ingot that has been worked into preliminary form in a hydraulic press. Corner radii on the flat dies of such a press should be about 4 in., to avoid cutting the ingot. The billet may be scalped, on a milling machine or lathe, to remove surface defects.

Stock should be carefully laid out so as to take full advantage of the grain flow produced by the forging process, placing the best structure at points of highest stress in the final forging.

For press forging, more careful preparation of the stock is required than in hammer forging. A blank must be cut for each finished piece, whereas a number of hammer forgings can frequently be made from one length of bar. The former method produces a minimum amount of flash, and uses from 15 to 20% less material due to closer cutting of stock to finished form.

Bars may be cut to length on a hand saw or circular saw if the saw marks will not be objectionable.

Aluminum stock for forging should be heated uniformly. This is especially important because of the narrow working range of the metal. Heating methods are usually such as to preclude overheating, but working cold metal in the forging dies will produce forgings having erratic physical properties. Die life will be reduced also.

Rough-shaping and drawing-out of the metal may be done with the fuller or edger so that the metal will completely fill the blocking die in the rough shaping operation. A bender, blocker and finish impression die might follow. The dies used, and their sequence, will, of course, depend upon the shape of the piece being forged.

Some forms require bends of such size or shape that they are not easily built into the die. In these cases a bending or twisting operation separate from the forging die will frequently be economical. The bending may be done while the metal is still hot, or, in some cases, after it has cooled. Proper allowance for such bending or twisting should be made in designing the piece, and radii of bends should be not less than twice the thickness of the work at the point where the bend is made.

When holes are to be made in some part of the work, a depression should be forged out until only about ⅛ to ¼ in. of metal remains. This may then be punched out hot.

The use of light hammer blows will help to eliminate blistering of the stock. Blistering, when due to the forging operation, has been associated with the heat of friction generated by working the metal. Proper finish of die faces, use of the correct die lubricant and, occasionally, the use of fullers, help to reduce the tendency to this defect in aluminum alloy stock.

Lubricants

Only enough lubricant should be used to prevent the work from sticking to the die. Use of excessive amounts of lubricant makes necessary a greater amount of cleaning of the finished piece. Lubricants in common use are mixtures of oils, salt water, oil and graphite, molten beeswax, and combinations of waxes and graphite. Beeswax is probably the best, but is high in cost. Graphite-wax mixtures are commonly substituted for it.

Combinations of high viscosity oil, of mineral, animal, or vegetable base, with low viscosity oil were recommended by the SAE War Engineering Committee after a canvass of a number of users. The viscosity of the oil may vary with the particular forging being produced. The high viscosity oil is the actual lubricant, and lard oil, plain mineral oil, peanut oil, castor oil, and others have been used. A thinning with low viscosity oil, which may be any solvent, such as distillate, permits the lubricant to spread over the die surface. A mixture of 50% lard oil and 50% distillate is typical. A small amount of graphite may be added if desired.

Application of the lubricant may be accomplished by spray or swab.

Dies should be carefully preheated to about 250 to 400 F. before starting operations, and especial care should be taken with the first blows. The use of cold dies has been listed as one of the leading causes of die breakage.

Prepared by Kenneth Rose, Engineering Editor


BE READY WHEN THE BELLS RING
RECONVERSION to peacetime production will require much redesigning, replacement, and repair work. If it's Bronze Castings or Bearings you need—we're ready. Whether your blueprints call for giant castings or pygmy parts—in the rough or precision-machined—we can make them. Our experimental foundry and modern laboratories stand by to work with you on the solution of your metallurgical or mechanical problems.
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NBM
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PLANTS IN: ST. LOUIS, MO. · PITTSBURGH, PA. · MEADVILLE, PA. · JERSEY CITY, N. J. · PORTSMOUTH, VA. · ST. PAUL, MINN. · CHICAGO, ILL.

NUMBER 64
November, 1944

Specifying Copper and Copper Alloys

When ordering or specifying copper or copper alloys, there are a number of items to be considered and included as well as certain customs regarding terminology that are generally used; many of these are cataloged in this *Engineering File Facts* page.

Standardized Names

ASTM Standardized Material Name	Average Composition	Reference See *Engineering File Facts*
Copper	99.2+% Cu	No. 11, May 1943
Brass	Cu-Zn alloys with Sn less than Zn; Pb (max.) ½%	No. 12, May 1943
Leaded brass	Same as above except Pb over ½%	No. 14, June 1943
Silicon brass	Si over ½% and Zn over 3%	No. 34, Jan. 1944
Nickel brass (German silver)	Zn over 10%, Pb (max.) ½%; sufficient Ni to give white color	No. 42, Mar. 1944
Leaded nickel brass (leaded German silver)	Same as above except Pb over ½%	No. 42, Mar. 1944
Tin bronze	Cu-Sn alloys with Zn less than Sn; Pb (max.) ½%	No. 16, July 1943
Leaded tin bronze	Same as above, Pb over ½%	No. 23, Sept. 1943
Nickel bronze (German silver)	Over 10% Ni, Zn less than Ni, under 10% Sn, Pb (max.) ½%	No. 42, Mar. 1944
Leaded nickel bronze (leaded German silver)	Same as above except Pb over ½%	No. 42, Mar. 1944
Aluminum bronze	5-15% Al; up to 10% Fe; with or without Mn or Ni; Si (max.) ½%	No. 30, Nov. 1943
Silicon bronze	Over ½% Si; Zn (max.) 3%; Cu (max.) 98%	No. 34, Jan. 1944
Beryllium bronze	Over 2% Be, or Be+metals other than Cu	Forthcoming

If the material is ordered by one of the standard material specification numbers (SAE, ASTM, Federal, etc.), then its analysis is expected to conform to these standards. On the other hand, if the material is not of standard composition, then its complete analysis (including the permissible variations in percentage of each element present) should be given.

Form

The form and/or shape in which the copper alloys are desired must be clearly specified, as there is a wide variety of choices. Copper for remelting and as a raw material for making copper alloys is usually sold in the form of cathodes, ingots or "warmer bars". Copper that is to be used for wrought products is marketed as wire bars (for rolling into rod or drawing into wire), cakes, slabs (cakes and slabs are usually rolled into sheets), and billets (for making tubing or extruded and rolled shapes). Brass products may be sand, permanent mold or die cast; forged, extruded, rolled or cold drawn. Bronze products may be sand or centrifugally cast or hot or cold worked, depending upon the analysis of the material.

When purchasing finished or semi-finished forms of the wrought materials, the type and degree of finish and size (including acceptable size tolerances) should be specified.

The amount of cold work performed on both commercial copper and its alloys affects the physical properties of the product noticeably. For example, the tensile strength of hot rolled or annealed copper is 30,000 to 36,000 p.s.i., but after extensive cold working, it is increased to almost 70,000 p.s.i.

The amount of cold work performed is commonly indicated by B & S numbers hard. All brass sheet, strip and wire sizes are based on Brown and Sharpe gage units. If a piece of sheet brass is cold rolled from number 12 B & S gage to number 13 B & S gage thickness, it said to be 1-number hard; if this sheet were reduced from number 12 to number 16 B & S gage, it would be 4-numbers hard.

Commercial Tempers

Commercial Temper Designation—Cold Worked Brass	Standard Abbreviations	B & S Numbers Hard	Sheet and Strip, % Reduction in Thickness	Wire, % Reduction in Area
Eighth hard	⅛ H	½	6	11
Quarter hard	¼ H	1	11	21
Half hard	½ H	2	21	37
Three-quarters hard	¾ H	3	29	50
Hard	—	4	37	60
Extra hard	—	6	50	75
Spring	—	8	61	84
Extra spring	—	10	69	90

A different range of physical properties is obtained for each number of hardness. As the percentage reduction increases, the hardness and tensile strength increase and, at the same time, the ductility decreases.

Grain Size of Copper Alloys

After hot working, or after cold working and annealing, the grain size of the material is used as an indication of its physical properties or of the degree of anneal to which the material has been subjected.

ASTM Standard Temper Nominal Grain Sizes in Mm.	Temper Name
0.015	Light anneal
0.025	
0.035	Drawing or rod anneal
0.050	Intermediate anneal
0.070	Soft anneal
0.120	Dead soft anneal

For electrical purposes, the conductivity of copper and of certain alloys (such as phosphor-copper and beryllium-copper) is important and an acceptable minimum should be noted.

Tensile strength, elastic limit, hardness, as measured on the Rockwell B (Rb) or Brinell (500 kg. load and 10-mm. ball) scales, elongation and bend tests are often included in specifications. Permissible tolerances or variations in these qualities should always be indicated, unless the variations permitted by one of the standard specifications are called for.

Prepared by Robert S. Burpo, Jr.

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Looking forward to the use of tubing for an ever-wider variety of mechanical uses, the large well-equipped laboratories of Babcock & Wilcox maintain uninterrupted research. Technicians seek constantly to improve present alloys and to discover, if possible, better alloys to meet the expected demand. B&W Tubing is now available in carbon steels, carbon - molybdenum steels, special B&W Croloys, NE. and S.A.E. Alloys, stainless and corrosion-resistant steels.

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6406

METALS and ALLOYS
Engineering File Facts

NUMBER 65
November, 1944

MATERIALS AND DESIGN
Welding

Welding Electrodes for A.S.T.M. Fittings

SPECIFICATION A-181-42
(Forged Fittings for General Service)

Chemical Analysis

Element	Grade I %	Grade II %
Carbon, max.	0.35[a]	(a)
Manganese, max.	0.90	0.90
Phosphorus, max.	0.05	0.05[b]
Sulphur, max.	0.05	0.05[b]

(a) The carbon content shall be a matter of agreement. Flanges subject to fusion welding shall not exceed carbon content of 0.35%. When so restricted it may be necessary to add silicon to the composition for Grade II and for heavier thickness of Grade I flanges in order to meet required tensile properties. Silicon not to exceed 0.30%.

Tensile Requirements

Properties	Grade I	Grade II	Electrode Recommended A.W.S.	
Ten. str., p.s.i., min.	60,000	70,000	E-6010 E-6020-6030	Grade I
Yield pt., p.s.i., min.	30,000	36,000	E-7010	
Elong. in 2 in., %, min.	22	18	E-7020-7030	Grade II

SPECIFICATION A-105-40
(Forged Fittings for High Temperatures)

Chemical Analysis

Element	Grade I %	Grade II %
Carbon	(a)	
Manganese, max.	0.90	0.90
Phosphorus, max.	0.05	0.05
Sulphur, max.	0.05	0.05

(a) When flanges will be subject to fusion welding, the carbon content shall not exceed 0.35%. When the carbon is restricted to 0.35% max., it may be necessary to add silicon to composition for Grade II and for heavier thickness of Grade I flanges in order to meet the required tensile properties. Silicon content not to exceed 0.30%.

Properties	Grade I	Grade II	Electrode Recommended A.W.S.	
Ten. str., p.s.i., min.	60,000	70,000		
Yield str., p.s.i., min.	30,000	36,000	E-6010 & E-6011	Grade I
Elong. in 2 in., %, min.	25	22	E-6020 & 6030	
Reduction of area, %, min.	38	30	E-7010 E-7020 & 7030	Grade II

SPECIFICATION A-182-40 F.1, F.2, F.3, Etc.
(Forged Fittings for Elevated Temperatures)
Chemical Analysis, Upper Table; Tensile Requirements, Lower Table

Type	Ferritic Steels							Austenitic Steels		
Identification Symbols	F.1	F.3	F.4	F.5	F.6	F.7	F.11	F.8	F.10	F.12
Grade	Carbon molybdenum	Chrome molybdenum	Nickel chrome molybdenum	4-6% Chrome	13% Chrome	Chrome molybdenum	Chrome manganese moly.	18 Chrome 8 nickel	20 Nickel 8 chrome	20 Nickel 8 chrome
Electrode recommended	A.W.S. E-7010 or equivalent	Chrome-moly. electrode if available, or Type 25-20	Same as for F.3	4%-6% chrome or Type 25-20	Difficult to weld; Use same analysis or Type 25-20	Same as F.3	Same as F.3	Stainless steel electrode Type 18-8 or equivalent[c]	Same as F.8	Same as F.8
Ten. str., p.s.i., min.	70,000	70,000	90,000	90,000	85,000	100,000	100,000	75,000	80,000	100,000
Yield str., p.s.i., min.	45,000	40,000	70,000	65,000	55,000	75,000	70,000	30,000	35,000	45,000
Elong. in 2 in., %, min.	25	20	18	22	25	18	17	45	40	50
Reduction of area, %, min.	35	40	50	50	60	50	30	50	60	60

[a] *Either molybdenum or tungsten shall be used.*
[b] *May be added.*
[c] *Sum of chromium and nickel contents shall not be less than 26%.*

Compiled by W. J. Conley, Consulting Engineer,
The Lincoln Electric Company Cleveland, Ohio.

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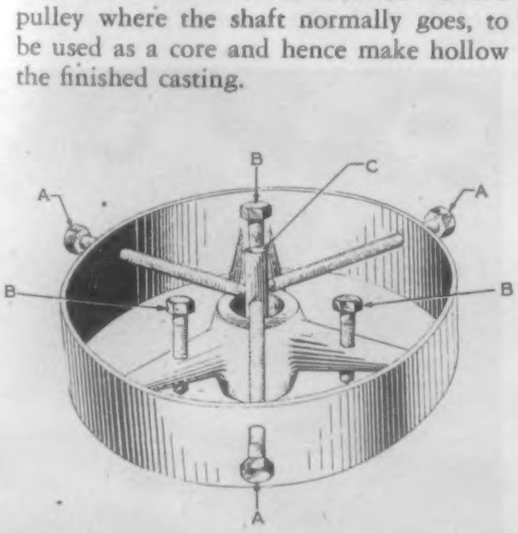
METALLURGICAL ENGINEERING shop notes

Old Pulley as Babbitting Jig

by Russell R. Voorhees, Pueblo, Colo.

A novel and useful jig for use where it is desired to cast babbitt into a cylindrical form, with hole in the center, is adapted from an old pulley. Fred Orman, Orman Construction Co., Pueblo, Colo., casts metal for many varied purposes with this homemade contraption.

The pulley is used in a horizontal position on the work table or floor. The original braces of the pulley are tapped out and leveling screws inserted so that the pulley can be accurately and easily leveled. A mandrel is inserted in the pulley where the shaft normally goes, to be used as a core and hence make hollow the finished casting.



The mandrel is centered and held in place during the pouring operation by three long screws, inserted where three holes have been tapped through the face, or belt runway, of the pulley.

Inside calipers are used to measure the space between the mandrel and sides of the shafting hole. When all adjustments of the screws are completed, the babbitt is poured into the space between the mandrel and shaft hole walls.

In the accompanying diagram, A indicates the long screws used to center the mandrel; B are the screws run through the braces to level the pulley; and C is the mandrel centered in the shaft hole.

Friction-Cutting with Drill Saw

by Arthur Schwartz, Bell Aircraft Corp.

We have hit upon a sawing method that we call "melting-burning." The friction of the saw tooth not only melts the metal, but turns most of it into gas, producing a flame under the sawing point. It may seem strange that a sharp saw is undesirable. Best results are obtained when the saw teeth are worn down to flats in line with each other so that each tooth will produce frictional heat.

Being tool research chief engineer at Bell's Elmwood plant, we were given the problem of finding a blade for a Tannewitz wood saw to cut boiler plate. After much research we lighted upon ordinary soft-tempered carbon steel blades. We adapted this to friction sawing of other hard materials, which had proved difficult or impossible to cut. We found these blades did an excellent job on armor plate, thick files, laminated plastics and the like which heretofore had withstood every attempt to cut them.

When the proper cutting pressure has been reached, a cobalt blue-white flame appears, indicating that the oxygen carried in by the spaces between the teeth is burning away the metal. It is not being sawed.

Some of the achievements reported by concerns that have adopted the method include cutting of carbide tool tips, stellite and similar tool tips, and heavy bricks of insulating glass. The Seattle Navy Yard has adapted extremely large saws to the cutting of armor plate. The Pittsburgh Plate Glass Co. is employing the method to trim plate glass.

The harder the material and the more resistance it offers, the more satisfactory are the results by this friction-sawing. It is ineffective on soft rubber, wood and some of the softer plastics.

We have had requests for our method from India, New Zealand, Iceland, England, South America, Russia and Mexico —in fact from all countries not Axis-dominated.

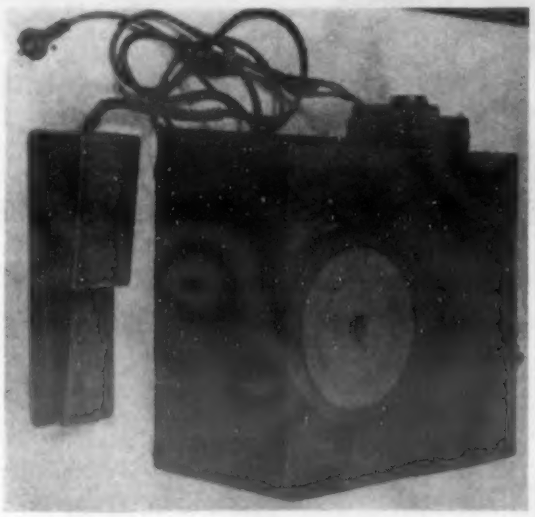
In soldering copper coil leads various steps consisted of scraping, tinning, twisting and soldering. A new method eliminates scraping insulation and using solder. Instead, we twist the leads together and apply an oxygen flame torch which instantly fuses the twisted ends into a ball of copper, making a solid joint.

—Walter Lindall, Submarine Signal Co.

Sander for Removing Burrs, etc.

by H. Small,
Westinghouse Electric & Mfg. Co.

A versatile home-made device for removing burrs, smoothing rivets and welded seams and for other general sanding operations that are normally performed by hand is a portable sander that is economical to operate and meets a multitude of unusual demands.



The 22 gage sheet metal enclosure, 9 in. high, 18 in. long and 16 in. wide, is built on a ½ in. thick steel base, on which are mounted a ¼ h.p. motor and a suitable bearing for carrying the sanding disc plate. The disc is carried on a revolving plate, 8½ in. diam., ¼ in. thick. Any desired grit may be used.

A washer and nut secure the discs, thus eliminating the necessity of cementing them to the plate. This machine is equipped with 5 ft. of electric cable and is operated by a foot switch. The disc is belt driven so that a fouled disc or too much pressure on it are overcome by belt slippage. Being completely enclosed, it is protected from dust off the disc.

This machine is used at the E. Springfield plant of Westinghouse.

Welding Flux to Prevent Tarnish

by M. E. Laune,
Eutectic Welding Alloys Co.

An easy method for keeping metals that are to be heat treated from tarnishing is by coating with welding flux. By one method the chemical compound that serves as a flux is slightly diluted with water and poured into a tank large enough to contain the part to be coated. The mixture is agitated to keep the heavier elements from settling, and the entire part is then submerged in it.

Another effective way is to coat the part by immersing it in flux that has been melted in a crucible or furnace. An actual application was reported recently by the maintenance foreman of a large Midwest manufacturing company. His department makes small tool steel reamers for reaming seats on welding torch fittings. With the tool, hundreds of worn welding torch parts are salvaged.

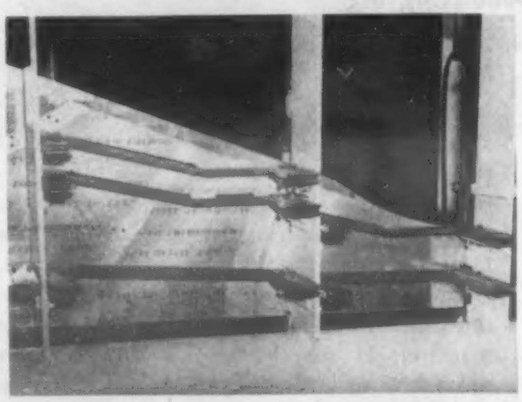
The reamer has a double taper that is turned as close as possible in a lathe, spotted and filed to a close fit in the female fitting and then the clearance later filed in by hand. During the subsequent hardening process, scale accumulated on the tool.

To overcome this, the entire surface of the tool was coated with a paste made of Autochemic Eutector Flux 16. The tool was then heated to the desired temperature, and immediately quenched in water. This procedure keeps the surface of the tool as bright and clean as before heat-treatment by preventing any oxidation.

Rivet-Bucking Assembly

by Morris Brown,
Consolidated Vultee Aircraft Corp.

Time studies have revealed that a new rivet-bucking assembly saves from 25 to 50% of the time previously required, while workmanship is improved. The assembly, invented by the author, can



be constructed in a variety of sizes and shapes and can be used on manual and automatic riveting jobs.

It consists of a "floating" bucking bar, positioned against the shank end of a rivet, and two or more spring-actuated reacting hammers, operating against the back side of the bar in response to impulses from a conventional pneumatic riveting gun. Gun impulses are transmitted through the bar to the hammers while the bar remains positioned against the upset end of the rivet.

Vibrations set up in the reacting hammers augment and oppose the impulses of the rivet gun and a specially-formed rubber stop, adjacent to each of the reacting hammers, helps hold the bar against the rivet by damping any tendency to vibrate.

One version of the assembly can be set up in a jig or fixture to function automatically, eliminating the rivet bucker. Another version has a handle and can be welded manually without tiring the workman.

When used with a jig or fixture, the floating portion is an elongated steel bar extending behind the entire row of rivets, supported at each end to the sides of the fixture or intermediate members by a device that guides the bar and supports the reacting hammer and dampers. The device is pivoted to the framework of the jig so that the bar is flexibly held, thus locating the bar against stringers or other reinforcements.

The bar may be curved or offset to accommodate the configurations of any line of rivets, even rivets of different sizes. A gage on each supporting device controls the size of the upset rivet head, promoting uniformity and preventing over-riveting. The gun operator knows when to stop by the change in the sound of his blows.

In the accompanying photograph the assembly has been set up as a jig to function automatically, with no human rivet bucker needed. Here the floating bars are curved to accommodate the configurations of the rows of rivets.

The author was inspired to invent this assembly after witnessing the condition of a young friend who was unable to hold up his arm after a hard day's work bucking rivets.

High Pressure Cylinders Wire-Wrapped

by Camilla McComber,
Newell-Emmet Co.

One of the many hazards of air warfare, one which is apparent to only a few persons, is the possibility that an enemy bullet or flak will pierce an oxygen or carbon dioxide cylinder in an Allied airplane. Due to terrific internal pressure these cylinders, containing gas for breathing or fire-fighting purposes, may thereupon explode into pieces of shrapnel, injuring the crew and the airplane.

Accordingly Walter Kidde & Co. now wraps each cylinder tightly with high-tensile steel wire so that a bullet leaves

a clean hole, with no fragmentation. The cylinder is spun at high speed and the wire is fed on under high tension in the same way that thread is fed onto a spool. The ends of the wire are soldered in place.

Metallurgical Engineering Digest

Metal Production

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric Furnace Melting Practice, Equipment and Refractories. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and Other Steel-Mill and Non-Ferrous Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill, Pickling and Heavy Forging Practice.

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1

Metal Production

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining • Open-Hearth, Bessemer, Electric Furnace Melting Practice, Equipment and Refractories • Melting and Manufacture of Non Ferrous Metals and Alloys • Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces • Steel and Non-Ferrous Rolling, Wire Mill, Pickling and Heavy Forging Practice

CONTENTS

Refractory Metals

Condensed from "Mining and Metallurgy"

The most important refractory metals today are tungsten, molybdenum and tantalum, with only the first two produced in quantity.

Tungsten ores are treated by pulverization; caustic alkali; repeated crystallization of the alkali tungstate; precipitation with hydrochloric acid to form tungstic acid; filtration, drying and pulverization of tungstic acid; and reduction with hydrogen. Briquettes are compressed and double sintered in hydrogen, first at 1100 C. to increase their strength, and then at a temperature close to their melting point.

The resulting bars are worked with frequent anneals by swaging or forging with hot drawing or hot rolling. The ductility produced by this hot working enables the tungsten to be cold drawn through cemented carbide and then through diamond dies. The grain size of incandescent lamp filaments must be closely controlled by additions of thoria or silica.

Molybdenum is produced from molybdenum sulfide or from commercially pure ammonium molybdate by methods similar to those used in the production of tungsten. Tantalum is made from purified tantalum salts. The manufacture of solid tantalum from tantalum powder is similar to that of tungsten except that the sintering and all subsequent anneals must be carried out in a high vacuum, and hot working is not possible because of the absorption of large amounts of gas.

A relatively large amount of refractory metal powders is converted into carbides for use in cemented carbides of which there are two main types: (1) plain carbide with a cobalt binder; and (2) multi-carbide of combinations of tungsten, titanium, tantalum or molybdenum, with cobalt or nickel as a binder. Cobalt is the most common binder, as it reacts less with the carbides during sintering than either iron or nickel and, therefore, has less brittle constituent.

The method of preparation of the raw materials is very important. The oxide is usually reduced in hydrogen, ball milled with lampblack and then carburized at a high temperature. Excessive amounts of free carbon must be avoided.

The cobalt reduced from the oxide is ball milled with the carbide powder of carefully controlled grain size. This powder is pressed, usually with an addition agent, such as wax or glycerine, and double sintered in hydrogen, first at about 1000 C. and then at 1400 to 1500 C. The compact may be shaped and machined after the first sinter.

Composite heavy metals contain about 90% W and are used for radium containers, vibration dampers, balancing parts, etc. If copper and nickel in certain proportions are used for the binder, the sintering resembles that of the hard carbides.

—C. G. Goetzel. *Mining & Metallurgy*, Vol. 25, Aug. 1944, pp. 373-375.

Phosphorus in Basic Duplexing

Condensed from "Stahl und Eisen"

The difficulties in producing a low-phosphorus metal of sufficiently high temperature in the converter are to a certain extent overcome by the great advantages in the open-hearth furnace. In order to find the metallurgically and economically most favorable phosphorus content of the converter charge and of the open-hearth charge for the production of a mild steel, the metallurgical conditions in the different processes were investigated.

The variously high phosphorus contents in the converter iron down to 0.03% were obtained simply by further blowing of the steel with the necessary lime addition. The iron loss connected with producing such iron with 0.04% P is about 7%, and almost twice as much as with producing steel with 0.08 to 0.10% P. The low phosphorus contents below 0.05% could also be obtained by after-blowing with a lime-rolling scale mixture.

By artificially enriching the slag with iron oxides, the total iron loss could be reduced by 2%, as compared with the simple afterblow. This still means a loss of about 2% Fe as compared with melts of 0.08 to 0.10% P.

The advantages realized in the open-hearth furnace with decreasing phosphorus content of the charge depend on the type of steel to be made, especially on its hardness. For very low phosphorus charges, *i.e.* low phosphorus content of the converter iron, the advantages realizable in the open-hearth furnace are overshadowed by the disadvantages in the converter plant.

Considering the duplex process as a whole, the most favorable phosphorus content of the open-hearth charge for soft melts, with an admissable phosphorus con-

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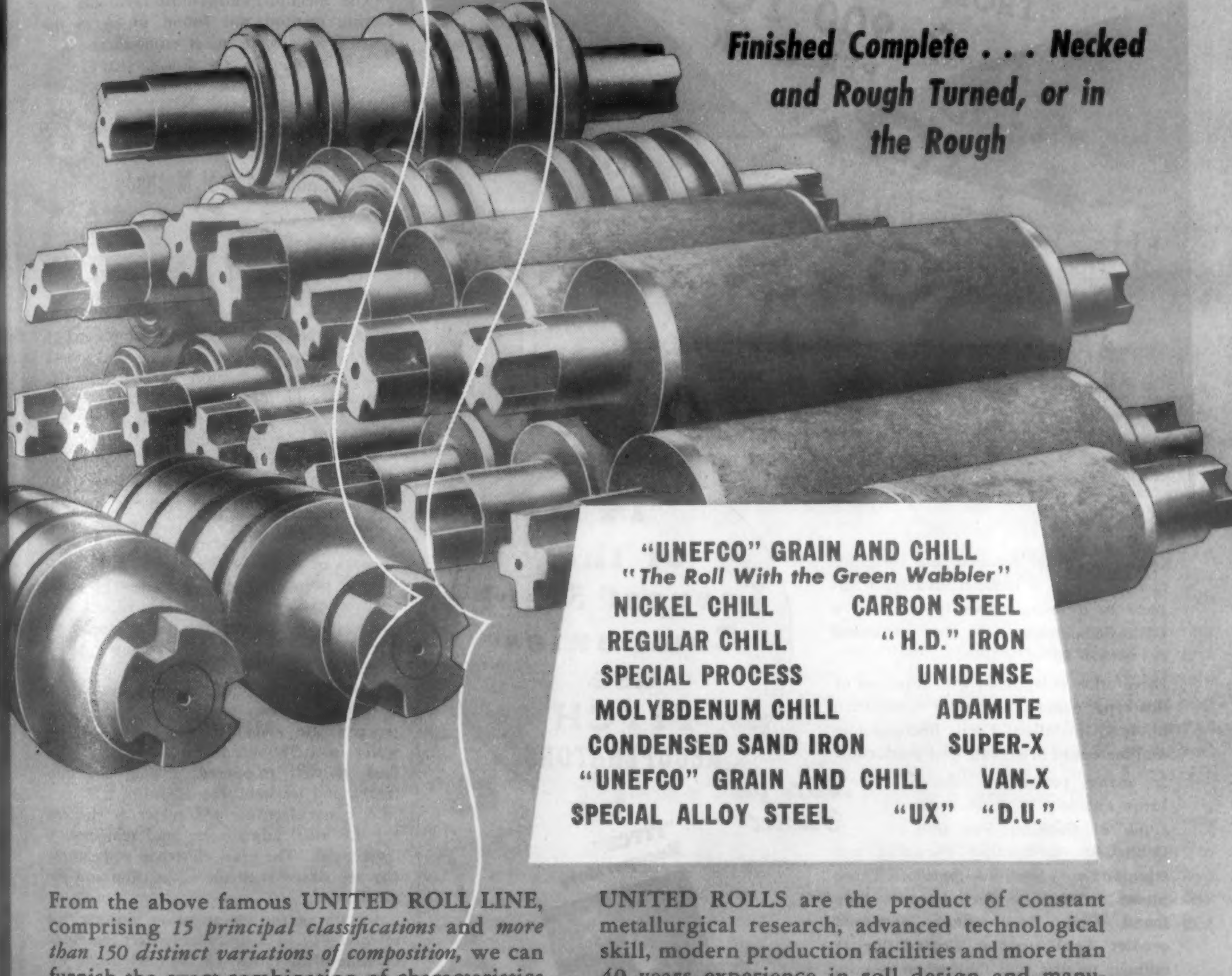

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tent of 0.05%, was found to be 0.09 to 0.10%. This can be obtained with a phosphorus content of the converter iron of 0.09%, if the converter slag is kept away from the open-hearth furnace by proper means.

Compared with melts with a higher phosphorus charge, an improved steel quality besides a considerably higher manganese yield was found. Only for harder types of steel, especially if a low phosphorus content is required besides a high manganese and silicon content, the advantages realizable in the open-hearth furnace with a further reduction of the phosphorus charge justify a further dephosphorization of the converter iron.

The metallurgically most favorable operating method was found to be at the same time also the most economical.

—H. Buchheltz & K. Debuch, *Stahl u. Eisen*, Vol. 63, Oct. 28, 1943, pp. 777-784.

Slag Control Methods

Condensed from "Blast Furnace and Steel Plant"

Five possible methods of estimating composition of slag for control of open-hearth heats were investigated. These were (1) visual inspection of pancake samples; (2) visual examination of powdered slags; (3) microscopic examination of polished slag samples; (4) measurement of the basicity of suspensions of powdered slag in distilled water; and (5) determination of "free CaO" by chemical methods similar to those used for cement clinker. The chemical composition of the slag was used as the basis of comparison.

Method (4) is a new technique that appears to have some promise, but it has not yet been applied to practice. The procedure involves crushing the cooled slag lump until all the sample passes a 40-mesh screen, removing iron, and mixing the slag well. Then, at least 200 mg. of slag powder, which can be measured on the tip of a spatula without weighing, after a little practice, are added to about 100 ml. of water in a 250-ml. Erlenmeyer flask. The flask is well stoppered, shaken intermittently, and let stand for 10 min.

A glass electrode pH meter is checked for the usual adjustments and temperature corrections. The glass electrode and sample cup are rinsed with the suspension and the pH is read.

Results of the investigation indicate that method (1) is fairly reliable over the range of lime-silica ratios (V values) from 1.0 to 2.5, is somewhat less reliable from 2.5 to 3.0, and may be subject to serious errors in V ranges above 3.0. The interpretation of the pancake samples must be varied somewhat with the use of different charging practices in the same open-hearth shop.

Method (2) affords some estimation of both basicity and content of iron and manganese oxide, as the color of finely powdered open-hearth slag varies with the composition. With intensive study, this method might be useful for control purposes, but it is probably no better than pancake methods.

Method (3) is useful for following the maturing of the slag in the course of a

Magnefer The popular dead-burned dolomite. Used by the steel industry more than 25 years for basic open hearth and slag line maintenance. Magnefer has won acceptance as a dependable refractory, uniform in grain size and composition. For prompt shipment at all times, ample circulating stock is carried at the Maple Grove, Ohio, plant, located at the geographical center of the industry.

Syndolag A rice-size, dead-burned dolomite, with the same chemical and mineralogical properties as Magnefer, Syndolag is ideal for electric furnace hearth maintenance. Its smaller, sharp-angled grains, carefully proportioned as to sizing, have a steep angle of repose. This enables Syndolag to adhere well to steep banks. Smaller grains absorb heat quickly and consolidate readily in residual furnace heat.

Basifrit The original quick-setting magnesite refractory, for construction and repair of furnace hearths. Recommended especially for resurfacing old hearths, to prolong their useful life. For resurfacing, an old hearth is washed down about 6 inches to provide a sound foundation. Basifrit, burned in very quickly in successive thin applications, provides a clean new bottom, with minimum time lost from production.

Hearth Patch Fine-grained, fast-setting magnesia refractory designed for emergency repair of deep bottom holes in quickest possible manner. After slag and metal are cleaned from a hole, Hearth Patch is dumped into it, and leveled off. Repair is finished by surfacing with a two-inch layer of burned dolomite or magnesite. Patch settles down under operating temperature to become a smooth, long-lasting, dependable repair.

GUNMIX A new series of fine-grained, quick-setting, highly adhesive refractories, designed for rapid emplacement on furnace linings by air stream and water. The Gunmix and Gunmix Gun now available are intended primarily for maintaining hot sidewalls of basic electric steel furnaces. Also in successful use with soaking pits and small open hearth furnaces. Other Gunmixes of acid and neutral types, to be emplaced similarly, and larger capacity guns are in course of development.

RAMIX The original cold-ramming magnesia refractory, specially designed for new hearth construction in basic open hearth and basic electric steel furnaces. Ramix takes a quick air set and when subjected to operating temperature becomes an extremely dense, hard monolith, highly resistant to hydration. Now in use in hundreds of furnaces. Also widely used for major hearth repairs.

695 A strong plastic basic refractory designed for hot applications. Melting point well above 3600°F. 695 is widely used for making tap holes and spout linings, as well as for hot repairs at critical points in many types of metal furnaces, where conditions are severe and operating temperatures unusually high. Shipped in bags ready to use, requiring only tempering with water.

RAW DOLOMITE

Washed open hearth dolomite in standard ⅝-inch size.

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heat, but by itself does not give a sensitive estimate of the composition of the slag.

Method (4) is roughly equal in reliability to the pancake method over the V range from 1.5 to 2.5, and is definitely superior in estimating slag basicity above 2.5 V ratio.

Methods tried in (5) are useless for control of open-hearth slags.

—W. O. Philbrook & A. H. Jolly, Jr. *Blast Furnace & Steel Plant*, Vol. 32, July 1944, pp. 793-797; Aug. 1944, pp. 938-942.

Ingot Mold Life

Condensed from "Stahl und Eisen"

The life of chill molds depends mainly on three factors: dimensions, metallurgical influences, and operating conditions. The metallurgical influences are more closely investigated, particularly for steel ingot molds, these being chemical composition of the charge, melting process, tapping and pouring temperature, composition of the finished casting, and heat treatment.

The principal properties the mold must possess are good resistance to hottest temperatures, and high mechanical strength at elevated temperatures. A desirable structure for a mold is the ferritic with a not-too-small amount of laminar pearlite.

The carbon content should be as high as possible, up to and over 4% of which 85 to 90% should be graphite, besides 1.2 Sn and below 1% Si. Molds with more than 1.3% Mn cracked always at a life of less than 110 castings, so that a reduction of the manganese to about 0.8 seems advisable. The phosphorus content should be below 0.15% for reasons of preventing growth, and sulphur must not be more than 0.1%.

Copper is usually present at 0.1 to 0.2%, and is harmless. A chromium content is decidedly harmful, as the burning off of the chromium amounts to 30 to 40% in the cupola furnace, and in the open hearth furnace still to 10 to 20%; furthermore, chromium reduces the graphite-germinating effect.

A material with 0.65 V and 0.4% Ti (Norwegian Vanite-iron) increases life on an average of 4.8% and does not, therefore, offer much economical advantage. Nevertheless, vanadium has a favorable effect on the hot-strength and permanancy of dimensions in gray iron, and titanium on graphite formation.

A composition approved by long years of experience is: 3.6 C, 3.1 graphite, 1.5 Si, 0.8 Mn, max. 0.15 P, 0.1 S, 0.1 Cr and 0.15% Cu. The saturation degree of such cast iron is 95%.

A diagram is given showing the tensile strength as function of the saturation degree for round rods: at 95% saturation, rods of 70-, 50-, 30- and 20-mm. diam. have a tensile strength of 14, 19, 24 and 27 kg. per sq. mm., respectively. A heat treatment of the molds consisting of heating to 800 C. (stress-relieving annealing) and slow cooling to 300 had a favorable effect. The average life of such molds was 150 to 165 castings.

—B. Koros. *Stahl u. Eisen*, Vol. 64, Mar. 9, 1944, pp. 159-164.

Factors Affecting Ingot Surface

Condensed from "Iron and Steel Engineer"

This study covered the factors affecting the surface quality of semi-finished ingot products at the blooming mill. Five hundred heats of a low alloy steel with about 0.25 C, 0.75 to 0.85 Mn, 0.50 to 0.65 Si and 0.50 to 0.65% Cr were included.

The surface quality was evaluated in terms of a "breakage index"; increasing values of the breakage index indicate increasing surface defectiveness. The breakage index curves showed a trend similar to curves showing the per cent cold rolled material rejected for physical properties.

The effect to 5 to 30% scrap in the charge of the open hearth was investigated. The breakage index was lowest for 25 to 30% light scrap, up to 15 to 17% heavy scrap, and about 15% alloy scrap. The silicon content of the pig iron should not exceed 1%. When the finishing slags were in good fluid basicity, the final preliminary carbon and manganese were 0.10 to 0.12%, and 0.10 to 0.15%, respectively; these values also gave reasonably good surface quality.

The nearer the manganese/carbon ratio approached 1, the more favorable the rolling was at the blooming mill. The breakage index increased consistently with increasing sulfur and phosphorus. Increasing final FeO content of the slag from about 15 to about 30% decreased the breakage index.

Pitch was found to be the best ingot mold dressing. The breakage index was a minimum if the temperature of the ingot molds when they were dressed was 200 to 250 F. At this temperature, the pitch gave a bright, hard, enamel-like surface. The breakage index increased as the number of firecracked molds increased.

The lowest teeming temperature gave the smallest breakage index. A transfer time of 5½ hr. between teeming and charging gave the lowest breakage index. The lowest soaking pit temperature for charging the ingots gave the best results, while a total heating time of about 1 to 6 hr. was unfavorable.

The prime important factor and, perhaps, the most effective one is a well prepared ingot mold. The effective improvement made possible by proper mold preparation is about 37.0%. The average difference in surface quality between heats poured into coated and into uncoated molds (grouping the evaluated findings in each unit operation) are: 26.0% furnace charge and raw materials, 35.3% refining practices, and 38.7% mechanical handling.

—H. F. Lesso. *Iron & Steel Engr.*, Vol. 21, Aug. 1944, pp. 63-72.

Smelting Magnesium

Condensed from "Light Metal Age"

Salvaged magnesium, or "smelter's product", if properly processed, makes ingots of equal properties with those made solely from virgin metal. Furthermore, the sal-

vaged material has benefit of requiring a decreased superheating temperature, and the grain is finer. Contrary to most metals, magnesium improves upon each remelting cycle because of the reduction of grain size through each succeeding remelt operation.

Remelt material use will reduce the amount of superheating necessary to achieve high mechanical properties in castings, enabling a faster melting cycle, hence increased production. Crucible life will be stepped up and consumption of combustion gases reduced.

Nickel is harmful if present in amounts exceeding 0.005%. Nickel is easily picked up from a crucible containing over 0.50% Ni. As to copper, amounts not exceeding 0.07% are not harmful. Ingots should have a maximum of iron content of 0.007%, though this is impractical in normal foundry practice. Careful foundry operations should result in a casting having between 0.010 and 0.015% Fe.

As to silicon, some foundries find that an excess of 0.20% makes excessive shrinking of finished castings. We believe that an 0.07% Si pickup is maximum in good foundry practice, thus allowing for an 0.20% maximum in the finished casting, considering that salvaged or smelter ingot would contain not more than 0.13% Si. Some foundries note a decided decrease in corrosion resistance with over 0.05% Pb.

Phosphorus should be eliminated or decreased because it creates a peculiar black "burned" appearance on the casting surface, which produces dangerous sparks when a sharp tool contacts it. Calcium reduces burning during casting but should be kept to under 0.02%.

When charging, spatters are blended into a number of heats to minimize high silicon content. Drums of borings, with over 20% oil, are drained and dried. A small amount of oil is good, acting as an inhibitor against burning during the charging period. Melting temperature must be kept as low as possible, and melting cycles should be done in 90 min.

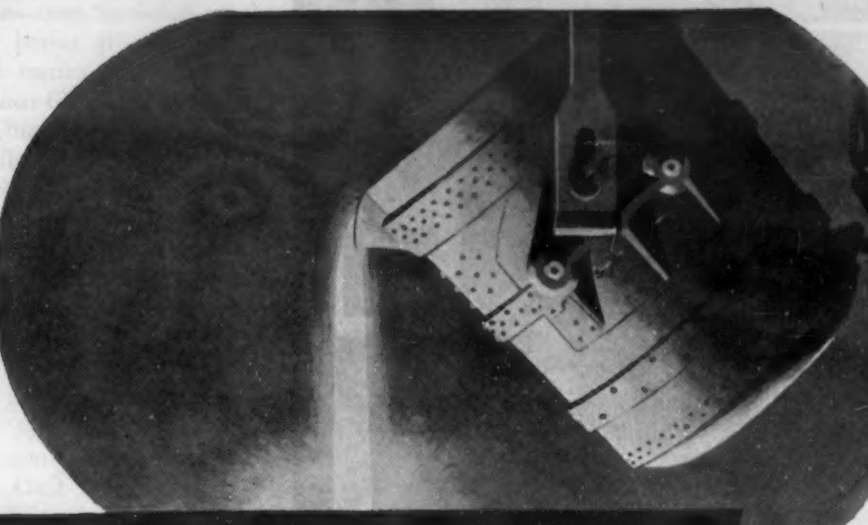
The charge is heated to 1290 F., then transferred to a preheated clean crucible, where it is brought up to an alloying temperature of 1390 F. Aluminum and zinc are added, if necessary, and 2% of refining flux by weight of total charge is added. A good pouring temperature is around 1230 F.

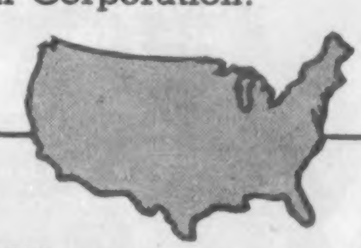
—W. B. Griffin. *Light Metal Age* Vol. 2, July 1944, pp. 17-18.

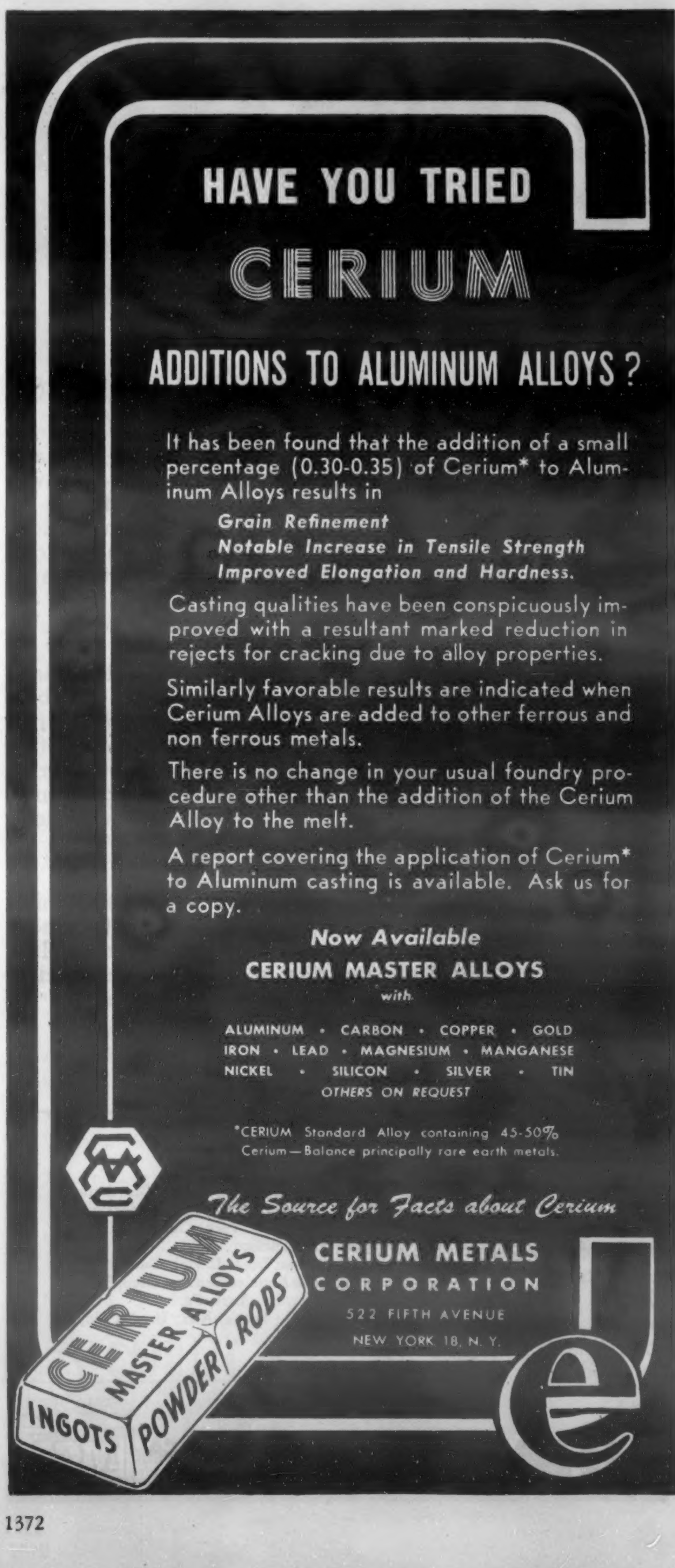
Quality of Silica Brick

Condensed from "Industrial Heating"

Service tests in which each half of an open-hearth roof is of different brand of brick show that certain brands are inferior, in spite of giving almost identical values. This is because the portion of a refractory under load becomes liquid, and is more readily attacked by fluxes. Therefore, the rate of wear bears a direct relationship to rate of formation and character of the liquid.







Liquid development is best determined by hot load tests in which the temperature is gradually raised until failure occurs. A 50-lb. load causes brick to fail when the calculated liquid content reaches about 18%.

Roof life has suffered seriously when alumina content of silica brick increased unduly. This possibility should be considered before ascribing lower roof life to the effect of hard driving or carelessness.

At 2% CaO, the temperature corresponding to 20% liquid changes from 3010 F. with 0.8% alumina to 2940 F. with 1.2% alumina. With 0.8% alumina, the percentage of liquid at 3000 F. passes through a minimum at 2% CaO. That is, there is a larger percentage of liquid with either more or less CaO. With 1.2% alumina, the minimum point is about 3% CaO.

An alumina content corresponding to 20% liquid at 3000 F. passes through a maximum at about 2.5% lime. For other percentages of liquid up to 28%, this maximum shifts to 3.25% lime.

The effect of alumina on temperature of failure in 50-lb. hot load test is linear, going from 3015 F. at 0.8% alumina to 2845 F. at 1.3% alumina. At this higher alumina content, experimental points range from 2800 to 2890 F.

—Frank G. Norris. *Ind. Heating*, Vol. 11, Aug. 1944, pp. 1316, 1318.

Enriched Air in the Blast Furnace

Condensed from "Stahl und Eisen"

An investigation as to whether the enriching of the air by oxygen would increase production in the blast furnace gave very promising results. The oxygen content was increased up to 26%. This could not be exceeded for operational reasons in the experimental furnaces.

The iron content in the ores amounted to 20 to 28%, in the sinter to 38.4%, and in rich Swedish ores from 50 to 62%. The burdens were composed of 100% low-iron ores and of 50% low-iron (domestic) and high-iron (foreign) ores.

Besides increase in production, considerable saving in coke was obtained. Roasting or sintering of the ores and using slaked lime instead of crude lime proved to be favorable and necessary to obtain the best effect of oxygen increase. If the burden is very dense and, therefore, the resistance to the gas passage high, the smaller quantities of gas with the enriched oxygen content facilitate the downward movement of the burden in the furnace and give better furnace operation.

The reason for the great reduction of the production for domestic (low-iron) ores is seen in the large quantities of slag and high coke consumption and the unfavorable space ratio between coke and ore, which further lowers the gas permeability of the burden of domestic ore.

The operation with oxygen was found to be 20 to 50% cheaper, even with little saving in coke after deduction of the cost for the oxygen, than the operation with normal air.

—W. Lennings. *Stahl u. Eisen*, Vol. 63, Oct. 21, 1943, pp. 757-767.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licking them with a Taylor 'pedigreed' product. For example, Taylor Zircon refractories are 'best of breed' for aluminum open hearth furnace bottoms and side walls to metal line, resulting in cleaner metals — more production. Inquiries receive immediate attention and careful study by Taylor engineers. Write for Bulletin 200.
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2 Foundry Practice

Melting and Pouring of Gray Iron, Malleable, Steel, Brass and Bronze, Aluminum and Magnesium Castings • Molding, Core-Making, Gating and Risering, etc. • Foundry Furnaces, Refractories, Ovens, Molds, Sands, Binders, Auxiliary Equipment and Materials

CONTENTS

Mechanical Handling in Foundries

Condensed from "Foundry Trade Journal"

The types of melting furnaces for which foundry handling methods are considered are the cupola and the converter open-hearth, electric, rotary and air. Cupola charging methods are by hand pulley block, electric pulley block, hoist or lift, skip hoists, drop bottom buckets, electric overhead travelling crane, conveyors. Converters are in most cases charged with molten metal, and this is usually transported from the melting furnace by an overhead travelling crane.

With hand molding it is necessary only to consider the handling of facing sand from the mills to the molder; the backing sand usually remains at the molder's side. In a fully mechanized sand system, sand is automatically returned from the knock-out station to an overhead hopper above the molding machines. Considerable convenience may be gained from using a unit sand, which has been proved to give excellent results.

Generally, the conveyors and elevators that are in use fall into five distinct types: Bucket elevators, tilting bucket conveyors, flat and troughed belt conveyors, scraper or push plate conveyors, and apron plate conveyors.

In foundries employing molding machines and mechanized sand handling systems, the following types of conveyors are available for molding flask handling: Roller track, overhead chain conveyor, plate-type floor conveyor, slat conveyor, and walking beam conveyor. Core sand may be delivered and discharged into storage bins in the same manner as molding sand.

Drying of core sand may be accomplished by a coal, coke or gas-fired stationary dryer, but if the sand contains a clay content in excess of 2%, it will not flow easily. For this type of sand, and where quantities in excess of ½ ton per hr. are required, it is more satisfactory to employ a rotary sand dryer, which may be fired by coal, coke, gas or oil.

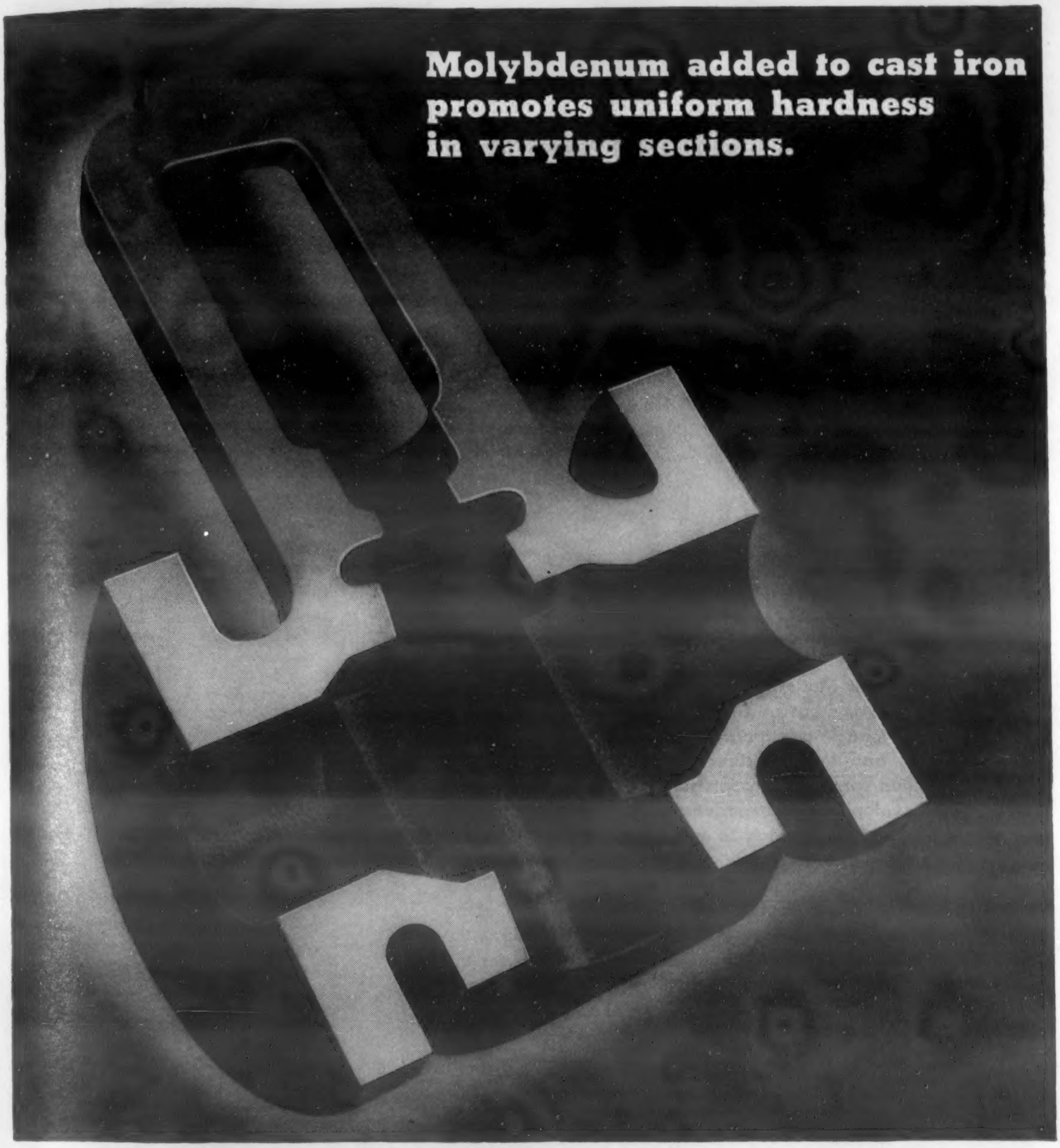
The feed to rotary-type dryers should be uniform, and may be effected by a drag link conveyor passing through the storage hopper and delivering into an elevator which, in turn, feeds the dryer. Before discharging from the dryer, the sand passes through a screen built into the dryer to eject waste materials that may be in the sand.

—*Foundry Trade J.*, Vol. 73, July 13, 1944, pp. 207-213; July 20, pp. 233-238; July 27, pp. 259-261.

Superheating Gray Cast Iron

Condensed from "Transactions" of the American Foundrymen's Association

It has been known for years that the structure and properties of ordinary cast irons depend upon variables of the melting process to as great an extent as upon normal variations in chemical composition. Much attention has been focused on "superheat-


Molybdenum added to cast iron
promotes uniform hardness
in varying sections.

ing" for assuring good mechanical strength. A metal is superheated when its temperature is raised above its liquidus temperature.

In 1935, Di Guilio and White experimented with an electric furnace. Data were obtained with accurate temperatures of superheating, constant pouring temperatures, and fairly constant analysis. Results showed increases in tensile strength up to superheating temperatures of 3000 F., then sharp declines.

Modulus of rupture and transverse strength increased with tensile strength and abruptly declined at 3050 F. They attributed the effects of superheating to graphite nuclei, primarily in the liquidus-solidus range. Pohl developed the possibility of a combination of time and temperature in the effects of superheating.

The present authors wanted to isolate the factors causing the effects of superheating. They now limit them to the influence of gases alone, particularly carbon monoxide and hydrogen. They found that the effects of superheating were not due to any nucleation mechanism and that they were probably due to variations in the gas content of the metal.

Water vapor increases the tensile strength slightly, and produces a flake graphite structure, indicating the water is reduced by carbon and the hydrogen thus formed influences the structure and properties of the metal.

Hydrogen eliminates ferrite, promotes the formation of flake graphite, and affects the tensile strength of the cast iron. The effects of superheating are essentially due to the presence of carbon monoxide, and modified to some extent by the hydrogen present.

Very little is known about the method by which these gases influence the structure of cast iron. The purpose of the carbon monoxide may be to catalyze the decomposition of iron carbide, accelerating graphitization. Hydrogen might remove carbon monoxide from the melt by the formation of methane and water vapor, and hence remove the mechanism for the graphitization of carbide.

—A. W. Schneble, Jr. & J. Chipman. *Trans., Am. Foundrymen's Assn.*, Vol. 52, Sept. 1944, pp. 113-158.

Bottom Pouring of Steel Castings

Condensed from "The Foundry"

In steel foundry operations, the molten metal is usually tapped into a ladle and then poured into molds. Usually a bottom-pour ladle is used. This ladle is a refractory-lined steel shell with a hole in the bottom close to the rim in which is inserted a refractory nozzle, usually made of clay. Fitting into the nozzle is the stopper, made of a graphite-clay mixture, mounted on the end of a steel rod protected by clay sleeves.

The stopper-rod assembly extending vertically through the metal in the ladle is fastened to a goose-neck which, in turn, is connected to a lever system. The flow of metal is controlled by raising and lowering the stopper in and out of the nozzle. These parts must give clean cut offs and open easily.

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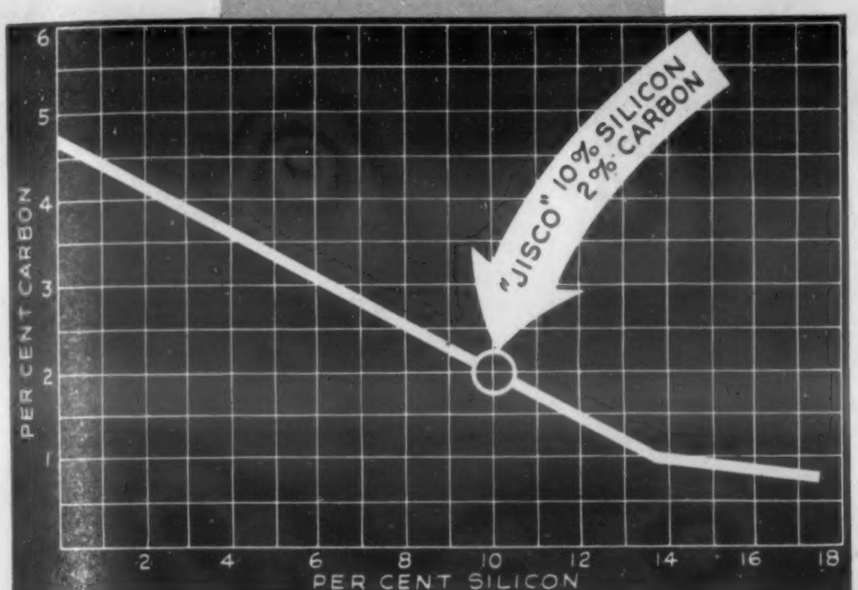
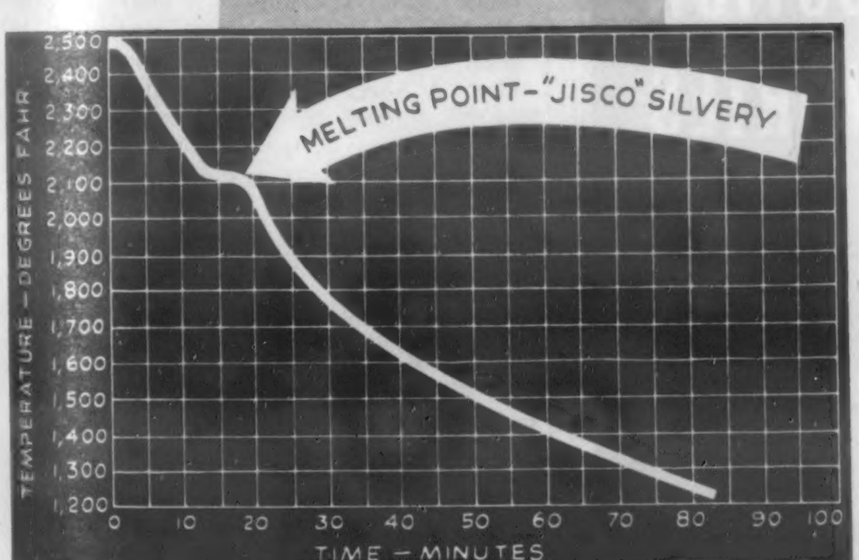


CARBON IN PIG IRON **No. 1**



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Requirements are severe, as often there are 150 ladle openings in an 80-ton heat that requires 1 hr. and 30 min. to pour. Refractory parts are subjected to high temperature, erosion of flowing metal under a ferrostatic head, and repeated openings and closings.

If the nozzle is sufficiently hard and refractory to withstand the erosion of the steel, the stopper head may not seat easily. A leak starts and gets worse. The seat of the nozzle must be soft enough to permit a stopper head to be pressed into it, otherwise leakage. The nozzle must not be too soft, for erosion will cause a leak.

If serious difficulty is encountered, an entire heat of steel may be lost, there is danger of burning the workmen, and messing up the place. Expensive patterns and other equipment may be damaged or destroyed.

Defects, such as scabs, cold-shuts and splashes, are encountered frequently as a result of faulty pouring technique. All mechanical equipment of the ladle must be in proper working order. Wearing parts should be inspected frequently. The nozzle must be placed properly in the ladle. The stopper rod and head must be assembled carefully and dried properly.

Allowance must be given for expansion when assembling the stopper rod. Setting of the stopper-rod assembly must be accurate. Allowance must be made for the ferrostatic swirling action of molten metal flowing through a funnel-like orifice. The stopper head should be ground to fit the contour of the nozzle.

Stopper heads are inspected with the longer wave length, low power X-rays, using a Westinghouse 200 milliampere fluoradex unit. The stopper is placed perpendicularly in the position of application to the rod, on a cassette containing the X-ray film. A 3-sec. exposure is sufficient.

—C. B. Jenni. *Foundry*, Vol. 72, Sept. 1944, pp. 68-69, 208.

Fume in Bronze Casting

Condensed from "Foundry Trade Journal"

The belief is still upheld in some quarters that to produce a sound manganese-bronze casting, it is essential that the metal should fume well during pouring. A test has been made to study the difference, if any, on the mechanical properties and microstructure of several castings of a standard shape in manganese bronze poured with varying degrees of zinc fume evolution.

It was found that over a wide range of temperature a sound casting was produced. There was no appreciable difference in alpha:beta ratio. The variation, which is very slight in ultimate and elongation figures, cannot be identified with rise or fall in pouring temperatures.

In short, a casting of given type (wedge type test bar cast in green sand) could be produced by pouring at 1090 or 890 C. (1990 or 1630 F.) to give the same final results.

—W. G. Moebrie. *Foundry Trade J.*, Vol. 73, May 25, 1944, pp. 71-72.

Metal-Working and Treating

3

Die Casting • Powder Metallurgy • Drop, Hammer and Upset Forging • Press-Forming, Drawing, Extruding and Stamping • Machining, Grinding and Polishing • Hardening, Tempering, Age-Hardening, Annealing and Malleableizing • Carburizing, Nitriding and Surface Hardening. Heating Furnaces, Refractories, Fuels and Auxiliaries • Welding, Flame-Cutting, Hardfacing, Brazing, Soldering and Riveting • Cleaning. Pickling, Degreasing and Sandblasting • Electroplating, Anodizing, Galvanizing, Metal-Spraying, Coloring, Buffing and Organic Finishing

CONTENTS

Spot Welding Heavy Steel Sections

Condensed from "Steel"

The International Harvester Co. is using at its Springfield, Ohio, plant the "Temp-A-Trol" process for spot welding mild steel attachments, ranging in thickness from No. 19 to No. 3 U.S.S. gage, to medium-carbon, medium-alloy steel plate panels.

This process insures uniformity of welds; permits mass production of welds of vastly higher quality than thought possible heretofore; makes possible for the first time the complete automatic heat treatment of spot welds in the spot-welding machine; allows visual inspection of the welds, as the temper colors developed during the heat-treating cycles furnish an accurate index of the physical characteristics of the weld; and permits use of relatively untrained operators.

With the new method, a wide range of thicknesses of metal can be welded with the same setting of the control panel, because the controls are actuated by the actual temperature of the weld and not by the length of time the current has been flowing nor by the total energy input.

An important factor contributing to the success of the process is the refrigeration of the electrodes with brine held at zero F. This makes possible successful use of a thermocouple imbedded in the electrode; gives rapid quenching of the welds; and helps maintain shape of the electrodes even at the high welding temperatures, pressures, and speeds used.

The complete cycle in welding the various assemblies consists of preheating, cooling and forging, welding, cooling and forging, refining grain, cooling and forging, and tempering. During the cooling periods, the pressure on the electrodes is increased about 50%. Identical pressures are applied to the electrodes for all heating periods.

The length of the cooling period after welding permits a martensitic condition to be attained in the weld zone. No external quenching medium is necessary because the great temperature differentials between the plate and the refrigerated electrodes give a quenching rate higher than that of the alloy steel used, The same dial that is used to control cooling after welding is used to control cooling after grain refinement.

Operation of the process and machine is controlled by an electronic system, actuated by an iron-constantan thermocouple. The latter is silver-soldered into the lower electrode so that the silver solder extends right up to the surface of the electrode and the hot junction occurs just below the surface of the electrode. Each heating period is also independently adjustable as to rate of flow of current.

Dials calibrated in degrees of temperature at the weld control actual functioning of the machine. These dials are merely set to values corresponding to the consecutive temperatures desired for each stage of the process.

Electrodes are made of a standard Group II electrode material, which is a copper-base alloy with a hardness of about 80 Rockwell B, and an electrical conductivity of 80 to 85% that of pure copper. The upper electrode is 1½ in. in diam. and the lower, 2½ in. Contact faces are ⅞ and 1¼ in., respectively. Both have centered electrode faces.

—Fred A. Lee. *Steel*, Vol. 115, Aug. 21, 1944, pp. 98-101, 144, 146, 148, 150, 152.

Corrosion Resistance of Lead Plate

Condensed from "Monthly Review", American Electroplaters' Society

The limited used of lead plating following World War I was due principally to (1) the lack of published data on the desirability of lead coatings, and (2) the lack of a satisfactory commercially available solution. At the present time, lead is being successfully used for corrosion protection in place of cadmium and zinc in many applications.

Lead-plated nuts, bolts and washers are satisfactory for ground contacts, since lead unlike zinc does not become coated with insulating corrosion products. Lead-plated springs are not embrittled as much as those plated with zinc in a cyanide bath.

The lead fluoborate type of plating bath is the most satisfactory developed to date. The difficulties and hazards involved in preparing this bath from hydrofluoric and boric acids and basic lead carbonate are eliminated by using lead fluoborate solution concentrates recently available commercially.

Lead coatings protect steel from corrosion in the salt spray test the following periods: 0.0001 in., 18 to 30 hr.; 0.00025 in., 25 hr.; 0.0005 in., 50 hr.; 0.001 in., 100 to 200 hr. In outdoor exposure tests at Woolwich, England, 0.001 in. of lead on steel showed a few rust spots after 6 mo., but after 3 yr. showed no rust, pores formed earlier having apparently sealed with corrosion products.

Exposure tests with galvanic couples in marine, industrial and desert atmospheres show that lead is more anodic to iron than either nickel or copper and, therefore, provides greater protection. It compares favorably with zinc in sea coast areas, but is inferior to zinc in industrial, rural and desert areas.

Lead-plated steel should not come in contact with aluminum or zinc. Lead does not accelerate the corrosion of copper, nickel, iron or tin. In all except strictly industrial atmospheres, these metals are protected by lead.

Reported advantages of copper plate under lead were not confirmed by the author. The same corrosion protection was given by 0.001 in. of lead as by 0.0005 in. of copper plus 0.0005 in. of lead. When a lead-plated part is to be soldered, a copper, or better still, tin plate under the lead is helpful, since lead on melting does not wet steel, but does wet copper or tin.

Lead-coated steel sheet can be spot-welded to steel, but not to another lead-coated sheet.

—John F. Beall. *Mo. Rev., Am. Electroplaters' Soc.*, Vol. 31, Aug. 1944, pp. 719-723.

Quenching Media

Condensed from "Edgar Allen News"

There are about 32 classified quenching media, all differing in their effect on the cooling rate, and about 26 types of different substances whose cooling powers have been carefully calculated. The more drastic quenches are required for steels of limited hardenability, the shallow-hardening steels, usually of unalloyed carbon type.

The commonest, cheapest, and simplest medium is water, and the next is brine. They have a high cooling rate (982 C per sec.), that is very close to the minimum rate necessary for plain carbon steels. Because this high rate tends to set up severe internal stresses, with consequent danger of distortion, the brine- or water-hardening steels cannot safely be used where warpage must be avoided.

Oil, with its slower cooling rate, reduces the danger of warpage. Oil-hardening steels contain suitable alloying elements,

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and so, in general, are more expensive than the plain carbon steels.

Whenever oil quenches with too much distortion, air may be used. Since even more of the alloying elements must be used in these air-hardening steels, they are usually higher in cost than the other types.

Other quenching media include liquid metals, and special salt solutions roughly intermediate between oil and water in cooling rates.

The action of the media is additionally affected by their temperatures at the time of quenching, and their cooling volume velocities, as well as the volume of the quenching tank, original temperature of the steel, and manner in which steel is quenched.

Four specific properties determine the quenching power of any medium: (1) thermal conductivity; (2) viscosity; (3) specific heat; and (4) the temperature at which it vaporizes or gasifies. As thermal conductivity is lower in the vaporized medium than in the liquid, those quenching substances liable to vaporize (*e.g.*, those containing water) should be used as cool as possible.

Introduction of calcium chloride or sodium hydroxide into aqueous solutions minimizes vaporization. Upon the other hand, soap has a reverse effect. The percentage of salt added to make up a quenching medium should be closely controlled, and usually will not be in excess of 10%.

In the case of oil, the cooling rate of the vapor at the vaporization stage is rather higher than that of the liquid, so vaporization is not so serious. While aqueous solutions are used cool, oil is preferably used warmed, at about 45 to 50 C.

Qualities desirable in oil in addition to the general characteristics given are: (1) minimum carbon content, and therefore the likelihood of less sedimentation; (2) low water content, to avoid a nonuniform cooling action; and (3) low content of certain fatty oils, which have unpleasant odors when hot, and also tend to decompose.

—Edwin Gregory & Eric N. Simons. *Edgar Allen News*, Vol. 23, July 1944, pp. 301-303.

Multi-Arc Welding of Aluminum

Condensed from a Paper of the American Welding Society

The welding process known as multi-arc was developed by the Materials Department of Curtiss-Wright Research Laboratory in Buffalo. The essentials of the process are the use of two sources of current, one a.c., the other a.c. or d.c., the first supplying a twin-carbon torch, the second a heavily-coated metallic electrode.

The twin carbon torch is held in the right hand so that the carbons are in a plane at 30° to the vertical, and are moved along the joint with the joint midway between the points of the carbons and about ⅛ in. below them. The metallic electrode

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In this application, the G-E current-regulating compensator enables the operator to use the press and gun welder interchangeably, when welding materials of the same thickness, without making any additional adjustments—even though the resistance of the portable secondary cable for the gun welder is appreciably greater than the resistance of the secondary circuit of the press welder.

THIS new current-regulating compensator will *automatically* correct for line-voltage variations and power factor, or impedance, changes, and will do it within three cycles. It will hold the current within plus or minus 2 per cent of normal, where changes would cause the unregulated current to vary as much as plus or minus 20 per cent.

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1. *Flexibility of Operation*—The same control settings can be used, and consistent results can be obtained when: (a) using a press-type spot welder; (b) using a gun welder connected to the same welding transformer; or (c) welding magnetic materials with a press- or gun-type welder with the material in or out of the throat of the welding machine.

2. *Improved Quality*—Without the use of this control, the introduction of material in the throat of the welder would cause unsatisfactory welds because of the changes in welding current. It would do so in many applications, such as in the welding of barrels, propeller blades, or large steel assemblies.

3. *Seldom Needs Adjustment*—After the operator has once determined the proper settings for an operation, no further adjustments are necessary—the current-regulating compensator takes care of variations.

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5. *Correlated Design*—This current-regulating compensator is designed for use only with G-E resistance-welding controls which include heat control by the phase-shift method. Complete interconnection diagrams are supplied to assist in installing this equipment.

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RESISTANCE-WELDING CONTROL

is held in the left hand and directly over the seam, in contact with the surface of the work.

During welding, the twin carbons and the metallic electrode are kept about 3/16 in. apart. Arcing takes place between the metallic electrode and the carbons, from one carbon to the other, from the metallic electrode to the work, and from one carbon to the work. The five individual arcs function as one. Immediate fusion of the metallic rod deposit and the parent metal results, with a weld uniform in quality and free from porosity.

The current supply for any one circuit is not sufficient to produce welding by itself. Because of the ionization produced by the carbon arc flame, a constant, smooth arc is maintained. Control of heat has been such that it has been possible to weld 0.016-in. 24ST Alclad aluminum alloy without a backing strip. While reverse polarity is preferred for welding aluminum, straight polarity may be used.

With the multi-arc welding process large amounts of heat can be delivered in concentrated form to the surface of the material being welded, while maintaining perfect control. The process permits the work to be preheated and the weld postheated, so that gases and impurities may escape to the surface of the metal. This evolvement of gases sometimes causes a surface roughness of the weld metal, but V-ray studies have shown the weld to be sound.

—M. R. Rivenburgh & C. W. Steward. Paper, *Am. Welding Soc.,* Oct. 16-19, 1944 meeting.

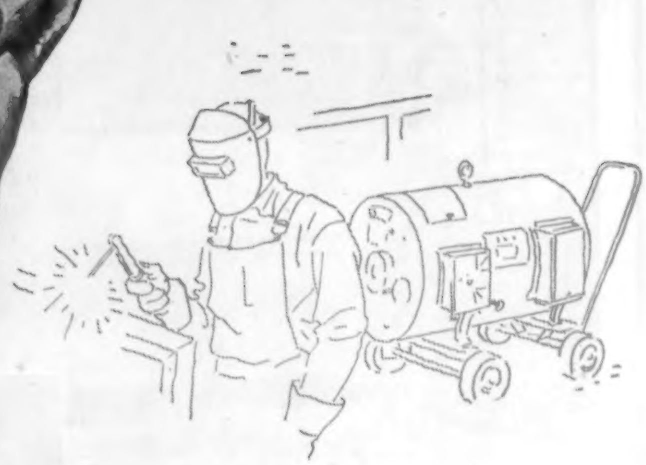
Coloration of Stainless Steels

Condensed from "Metal Finishing"

A black oxide film cannot be produced on stainless steel with the alkaline type of solution used for the blackening of ordinary steels. A solution that produces satisfactory films contains about 50% sulfuric acid, with small amounts of etch-inhibitor or a supplemental oxidizing agent. Etch-inhibitors may be taken from the vanadates, metavanadates, vanadic acid, or chromium salts of sodium and potassium. Chromium salts, in addition to being effective inhibitors, also serve as supplemental oxidizing agents.

The solution is operated at a temperature of from 165 to 210 F. It is essential that the tank lining be chemical, tellurium, or antimony lead, since the coloring reaction is electrolytic, with the tank wall serving as the cathode. However, no external current is supplied.

The operating procedure consists simply of immersing the alloy in the solution for definite periods of time ranging from about 19 min. to a maximum of 45 min., depending upon the thickness and color of film desired. When coloring is completed, the work is removed and rinsed with water. Processing results in a very small weight loss, but not enough to cause appreciable dimensional change. The final film, when



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AC-3 (E-6012 and E-6013)

For AC, and either polarity on DC. • Tensile strength, 65,000-70,000 P.S.I. • Yield, 55,000-60,000 P.S.I. • Ductility, (2") — 18% to 25%. • Available in all sizes — 14" and 18" lengths.

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no further action takes place, is about 0.0001 in. thick.

Steels with 7 to 22% Cr. give colors ranging from gray to deep chocolate. Alloys containing nickel in addition to chromium produce a still wider range of colors, including the above plus maroons, brass-golds and bronzes, with an end color approximating chrome green. Alloys containing small amounts of vanadium, tungsten or molybdenum produce vivid reds, blues, off-shade violet, and brown-yellow.

The films do not chip, peel, or craze. and have high ductility, but do not have much abrasion resistance. If desirable, their abrasion resistance can be increased about five fold by heating for 2 to 3 min. at 800 to 1700 F. Heating produces a slight loss of color.

The same solution used for coloring may, by introduction of an external current supply, be used for anodic cleaning, electrograining (etching), electropolishing, precision electro-etching of designs from lithographic "resist" printing, and electrolytic pickling.

The solution is easy to maintain and processing costs are low. All phases of the process are covered by patents issued or pending.

—Clements Batcheller. *Metal Finishing*, Vol. 42, Aug. 1944, pp. 466-469.

Copper Brazing in Production

Condensed from "Automotive and Aviation Industries"

The conveyorized copper brazing method is in sharp contrast to the extended transportation time element in welding processes. In this method, parts are assembled by unskilled labor, placed on the conveyor belt, and, after moving steadily through the process, they come off the other end clean and ready for plating.

With the melting point of copper about 1950 F., a temperature of 2050 to 2100 F. is used for brazing. This temperature, because it exceeds the heat treating temperature of low alloy steels, permits a heat treating operation after brazing.

To insure best results, controlled atmospheres consisting of charcoal generator gas, pure hydrogen, partially burned fuel gas, or a combination of the three, is used. The small Hoskins unit uses bottled hydrogen as a furnace atmosphere. To remove water vapor from bottled gas, a silica jell dehydrating unit is installed.

The General Electric furnace utilizes an atmosphere of partially burned fuel gas cooled to room temperature to remove water vapor. Carbon dioxide and oxygen are removed by passing gases through a retort containing charcoal.

At approximately 2000 F. reactions are complete and the carbon dioxide and water are reduced to small fractions of 1%. Heat is lost, and it is therefore necessary to add heat continuously to the carbon to maintain correct atmosphere.

The surface to be brazed must be clean and free from foreign metals that would interfere with producing a proper brazed joint. Plated parts must be stripped before brazing.

In order to insure capillary action, faying surfaces must not be highly polished, and there should be good metal to metal contact. Therefore, final cleaning consists of pickling and sandblasting.

The best design for copper brazing is a telescopic joint employing a diametrical clearance of 0.001 to 0.003 in. per in. of diam. One basic reason for a tight fit is that the shear strength of copper is 20,000 p.s.i.—the tighter the fit the higher the shear strength.

Although it is possible to use a brazing alloy having a melting point above the normalizing temperature of SAE 4130 steel, it is much better to braze with pure copper and reheat for normalizing or heat treatment to a higher tensile strength. Brazing alloys melting at lower temperatures than copper are not satisfactory.

Penetration of copper through the joint is effected by capillary action. At 2000 F., copper has the wetting action of alcohol. It is necessary only to place the proper amount of copper near the joint and, if parts have been cleaned properly, copper will be attracted through the joint. A flux is required for high zinc or tin alloys.

—C. L. Hibert. *Automotive & Aviation Inds.*, Vol. 91, Aug. 1, 1944, pp. 32-35, 67-68, 70, 74, 76, 78.

Tin in Die Casting

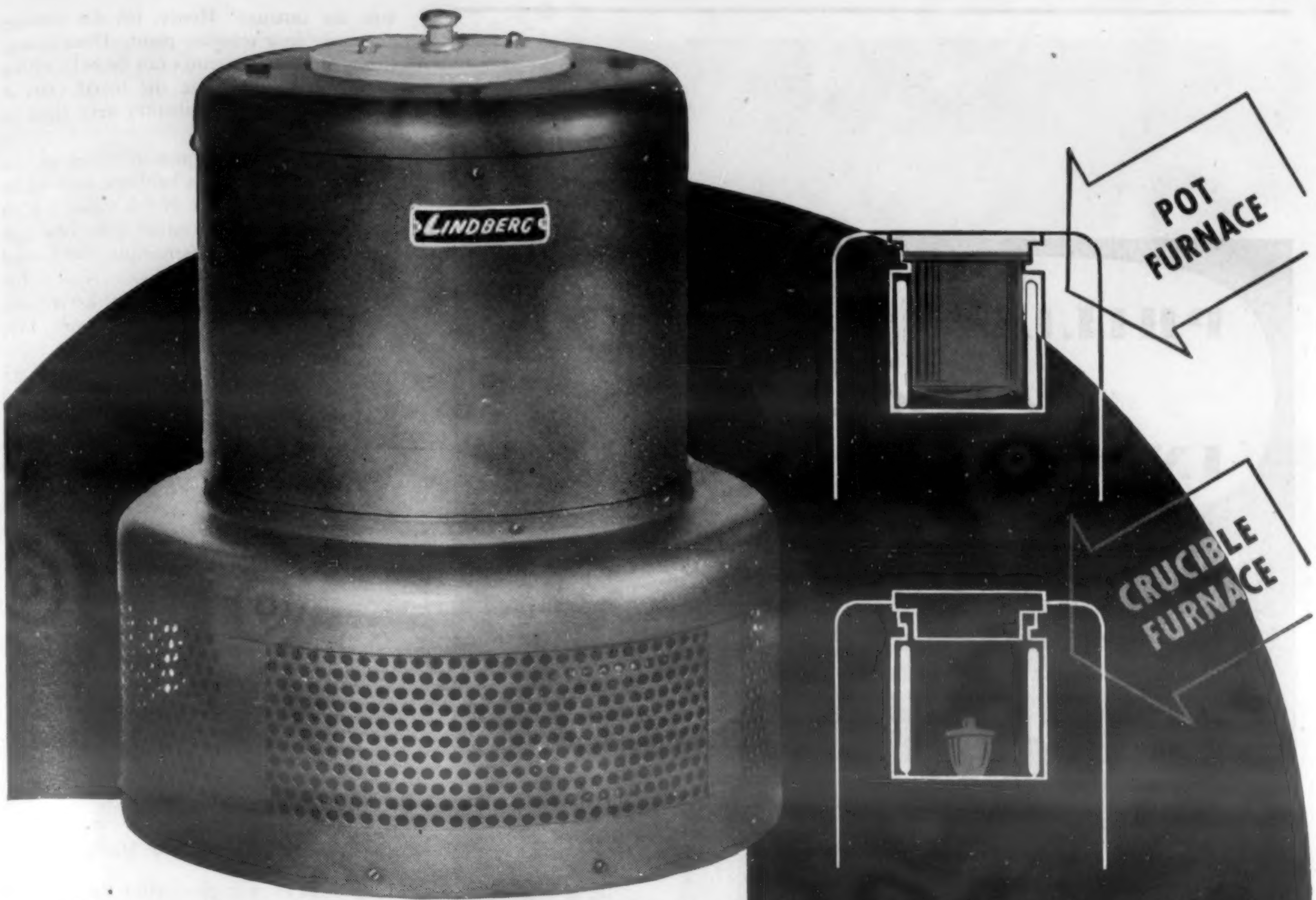
Condensed from "Die Casting"

The earliest alloys used extensively in commercial die casting were those based on tin, though the placing of tin on the critical list limited its use. Advantages are that they are high in corrosion resistance, can be cast at low temperatures, have excellent bearing properties, high dimensional stability, and ability to take a high luster without plating and for long duration. Excellent castability in a plunger machine and indefinite die life are also favorable.

The cost per pound is the highest of any die casting alloy except brass containing beryllium, and physical properties are about the lowest, including low strength under all headings, low ductility and low hardness, and a tendency to cold flow.

There are now two important uses: (1) In very small parts, as in counter and number wheels or instrument parts wherein the closest as-cast limits are essential, and where corrosion resistance to inks is needed; (2) in parts that come into contact with foods and beverages, where high corrosion resistance and non-toxic properties are essential. Less important uses are for the cheap jewelry trade because of high luster, appearance and corrosion resistance.

Since zinc alloys cannot tolerate tin impurities above 0.005% max., it is not safe to have any tin in a department making



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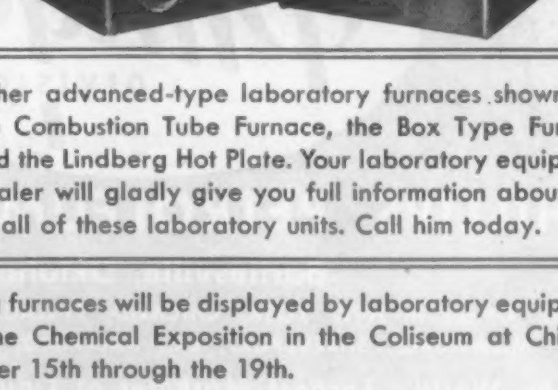

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zinc die castings. Hence, tin die castings are made in a separate plant. Dimensional limits on tin die castings can be held within slight variance because the metal casts at low temperature and shrinks very little in cooling.

There are three common types of die cast tin alloys, listed as babbitts, covered by A.S.T.M. specifications. No. 1 makes a high class bearing, though rather soft; No. 2 is harder resistant to tarnishing, and used where in contact with food; No. 3 has 18% Pb content, resulting in lower cost, but its tensile strength is relatively low, and it cannot be used with food.

Tin alloys are low in tensile strength and in elongation, being inferior to lead alloys, but this is minor for most applications. The melting point is low, 400 to 440 F., with casting temperature of 700 to 760 F., or not much lower than for zinc alloys.

—*Die Casting*, Vol. 2, Aug. 1944, pp. 47-49.

High-Speed Tapping

Condensed from "Modern Machine Shop"

Pressure of war production has brought radical changes in the design of tapping machines, greatly increasing speed and quality in light manufacturing operations. The application of individual motor drive was followed by speed changes for different diameters of taps, ball bearings, methods of lubricating, disposal of chips, built-in air control for automatically lowering and raising the spindle, and adjustable counterbalance for the spindle chuck and accessories, an automatic valve, controlling the tapping speeds "in" and "out," and a foot pedal with which the operator can start or stop the tapping cycles.

One tapping machine has a cone shaped friction clutch with three shoes of leather inside the cups to provide for expansion, contraction and long wear. In others the tap is controlled with a vertical lead screw, which can be exchanged for one that corresponds to the number of threads per in. to be tapped. The new machines also make possible the use of high-speed steel taps that are precision ground.

A good grade of lard oil is the best lubricant. It is expensive, and a mineral oil with a lard base may be substituted at times. Machine oils should never be used. Coolants are not necessary.

In tapping parts for rifles, a Haskins air-controlled tapping machine uses a two-fluted gun tap secured in the chuck. The tap is spiral pointed, but when two flutes are used it is called a "gun tap" or a "chip driver tap". The angle on the point drives the cuttings ahead, and when the tap is withdrawn, removes them from the hole. The work piece fits into a slot so that it does not turn with the tap.

(Continued on page 1396)

An example of tapping parts for aircraft is found in the use of a two fluted gun tap for a "through hole" ¼-in. deep. The tapping r.p.m. are 1250 and for backing out, 2500 r.p.m. This is high-speed tapping, producing 1200 pieces per hr. A swinging leaf fixture holds the work.

A right-angled vertical post tapping fixture designed with a cast iron sliding base for loading and unloading the work is illustrated as retapping a 9/16-in.—32 special thread in a steel gas cylinder used in rifles. Another efficient clamping fixture holds round work. It is an air-controlled vise that clamps and releases the work automatically by lowering and raising the spindle of the machine. The clamps are removable so that the jaws can be exchanged for others suitable for different sizes and shapes of work.

There is also a special dial-feed fixture for tapping 2500 holes per hr. in lower clamp plates. It holds two pieces of semicircular work, and both feed and return are controlled by air.

—C. W. Hinman. *Modern Machine Shop*, Vol. 17, Sept. 1944, pp. 164-166, 168, 170, 172, 174, 176, 178, 180, 182.

Plugging Blowholes by Welding

Condensed from "Welding Engineer"

The "nervous weld" process is a new method developed by the Metallizing Co. of America to plug blowholes or otherwise add metal to salvage castings, particularly aluminum.

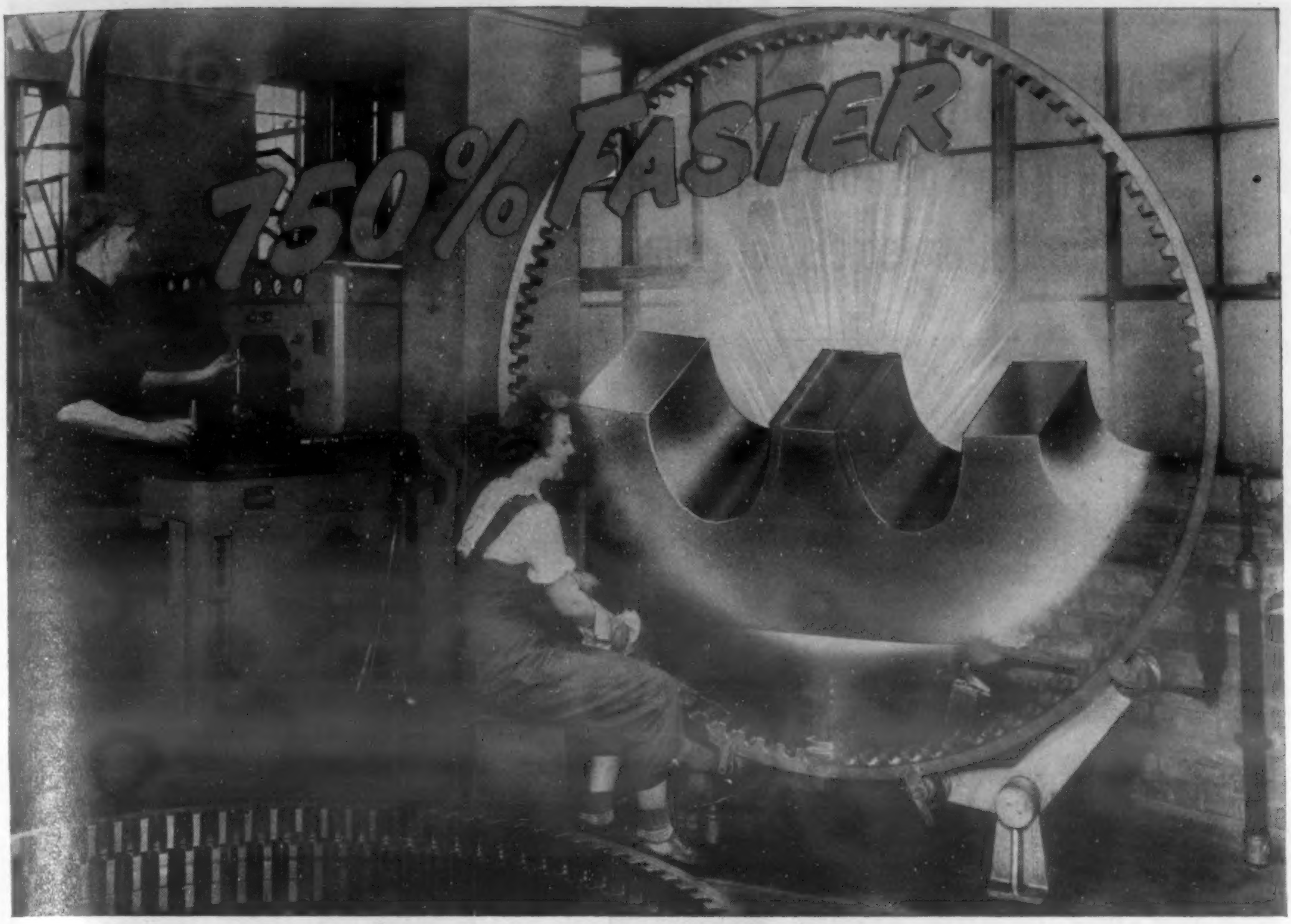
The necessary equipment is: a special transformer type welding machine operating on 110, 220, 440 or 550 v., single phase, a. c.; a pistol using about 5 cu. ft. per min. of compressed air at 40 to 60 p.s.i., having feed rolls and a trigger arrangement for manual feeding of the electrode. An air-cooled nozzle is also provided to keep the temperature of the material being welded under 125 F.

The surface to be repaired is contacted with an electrode of similar material. While in contact, the electrode soon is heated to the plastic stage when the pistol vibrator automatically pulls the rod away, leaving a "gob" of plastic metal on the surface. The recoil of the vibrator pounds and forges until the new metal is integral with the old.

The process differs from metallizing in that a homogeneous bond is formed rather than a mechanical bond caused by interlocking particles. A nickel electrode is used for steel, gray iron, malleable iron; a bronze electrode with low zinc for bronze; and an aluminum electrode for aluminum. There may be a slight discoloration in the first two cases.

In repairing defective aluminum castings, the density of the deposit is within 1 to 1.5% of that of the cast aluminum. Even a photomicrograph fails to reveal the boundary.

Several cases are given where this method has saved considerable time and labor: re-



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HERE is the report on Northern Pump Company's development of the TOCCO-hardening of gun training gears:

The 82″ ring gear shown above is TOCCO-hardened, one tooth at a time. In just 4 seconds, high frequency induction brings the 3″ wide wearing surface of the tooth to 1540° F. TOCCO's integral water-quench then instantly cools and hardens it. Handling and tooth indexing are all automatic. The 103 teeth of the gear are TOCCO-hardened in less than 18 minutes . . . 750% faster than the 2¼ hrs. required by the former method.

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pairing worn spots in core boxes, repairing pattern fillets, filling blowholes in powder loading trays, putting a boss on an aluminum pattern, and filling blowholes in aluminum bombsight castings. In the last application, a low temperature zinc alloy rod had proven unsatisfactory, since it would not stand up in alumilite plating. The castings could be alumilited satisfactorily when repaired with "nervous welding."

—C. B. Clason. *Welding Engr.*, Vol. 29, Aug. 1944, pp. 32-33.

Stress Relief of Low Alloy Steels

Condensed from a Paper of the American Welding Society

Some trouble has been encountered in stress-relieving low alloy steel ordnance structures, since insufficient data are as yet available to determine the effects of time and temperature in the process. Experiments were made with standard 0.505-in. specimens, stressed in a fixture to a value slightly above the yield point. Stress relief treatments were then made upon specimen and fixture and the relaxation measured in the cooled specimen.

Steels used were SAE 4130, NE 8630, a copper-nickel-phosphorus steel in the 70,000 p.s.i. yield strength class, and two high tensile, low alloy steels in the 50,000 p.s.i. yield strength class, one a carbon-manganese, the other a manganese-silicon-chromium steel.

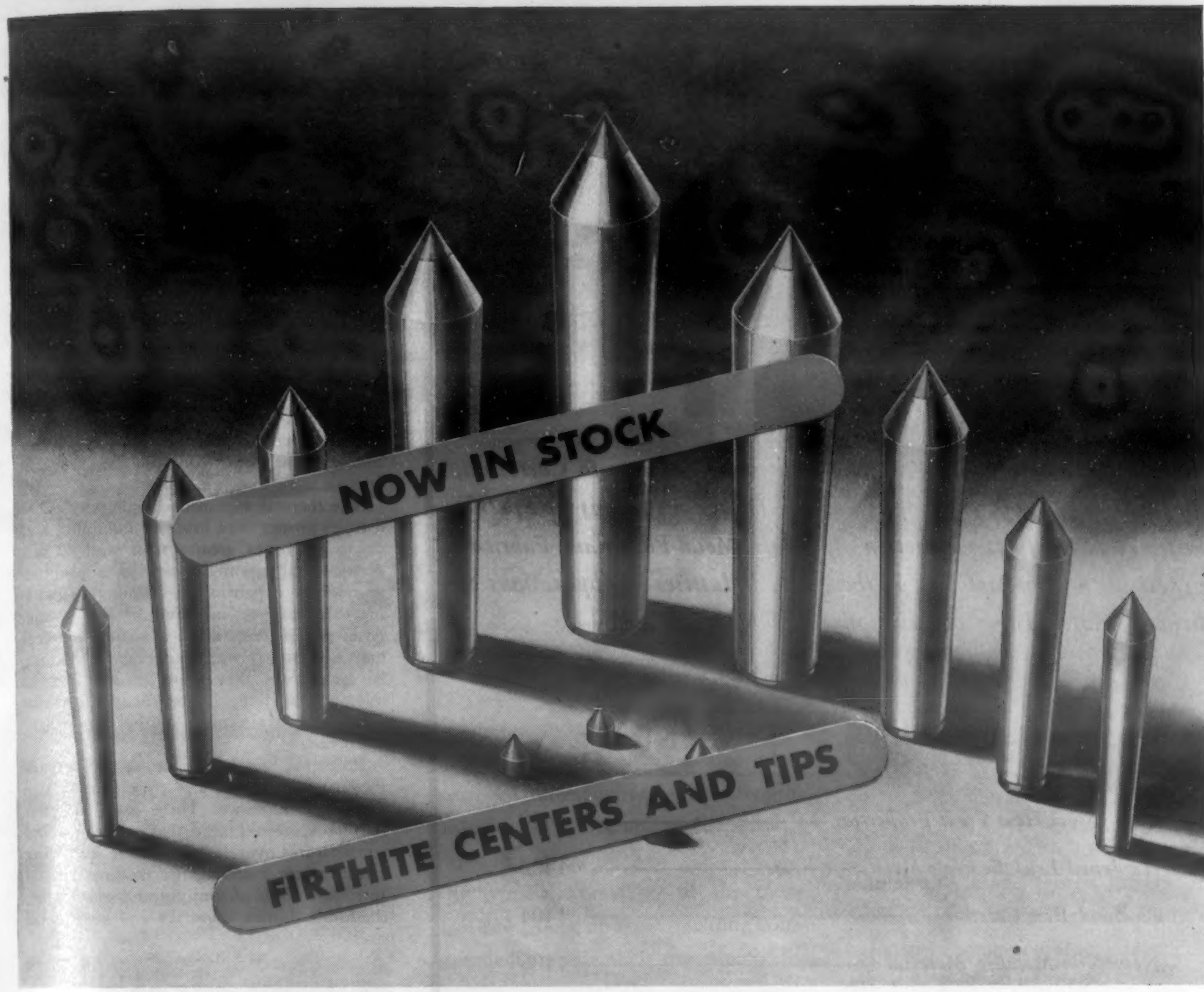
Treatments of one, four, and eight hr. at 900 F., 1000 F., 1100 F., and 1200 F. were made for all steels. Graphs made of the results indicate that no two steels react exactly alike to the treatments. However, the high tensile low alloy steels in general reacted similarly as did the SAE 4130 and NE 8630.

To reduce residual stresses to values below 10,000 p.s.i. minimum heat treatments were shown to be: For the high tensile low alloy steels used, eight hr. at 1000 F. or one hr. at 1100 F.; for the copper-nickel-phosphorus steel, four hr. at 1100 F., for the NE 8630, one hr. at 1100 F.; for the SAE 4130, one hr. at 1100 F. or four hr. at 1000 F.

A heat treatment of one hr. at 1200 F. reduced residual stresses to 2500 p.s.i. or less on all steels except the copper-nickel-phosphorus, which required eight hr. at 1200 F.

Test results seemed to show that the degree of stress relief is affected more by temperature than by time at temperature; that different steels, when stressed, do not react alike to stress relief treatment; that the increase in percent stress relief is not uniform as temperature or time at temperature is increased, but that, with few exceptions, the percent increase is greatest as temperature is raised from 900 F. to 1000 F.; and that the effect of time at temperature is more pronounced at the lower temperatures.

—Lt.-Col. Paul C. Cunnick & J. K. McDowell. Paper, *Am. Welding Soc.*, Oct. 16-19, 1944 meeting.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CONTENTS

Thermal Properties of Plastics

Condensed from "Product Engineering"

The true thermal properties of a material are thermal expansion, thermal conductivity, specific heat, and thermal emissivity. Softening and distortion points are associated properties, and they indicate the basic differences between thermoplastic and thermosetting resinous materials.

In the field of heat resistance, "maximum safe continuous operating temperature" is an arbitrary value for a given material used on a given product. It is that temperature at which the material will not become blistered or distorted or sustain an appreciable loss in appearance or mechanical strength.

The A.S.T.M. test measures the amount of deflection of a simple beam under a prescribed load. The temperature at which the beam deflects 10 mils is known as the heat distortion point.

Thermoplastic materials are easily distorted at temperatures that are inconveniently critical—the temperature of boiling water, at which much industrial apparatus operates and to which outdoor appliances are frequently subjected. Here thermoplastics must be used with caution. But research may someday improve performance.

Thermosetting materials readily withstand these temperatures but have similar limits that must not be exceeded. Phenolics, ureas and melamines do not fail by softening, but rather by loss of mechanical strength or appearance because of overheating of the filler material or the resin itself.

Plastics in Insulators

Thermal conductivity must be investigated in design work when an insulating material for refrigerators, wall panels or table mats is needed, or a material comfortable to the touch in cold weather, or where a cover or base for a heat generating assembly must dissipate the heat at a minimum rate.

Of particular interest are the expanded materials, which have a cellular structure that makes them good thermal insulators. All plastics are comfortable to the touch, compared with metals, because they do not conduct heat away from the hand rapidly enough to be uncomfortable.

The thermal expansion of plastics is 2 to 8 times greater than brass or aluminum and up to 15 times greater than steel. Thus, plastic-metal assemblies present a problem in unequal expansion, resulting in distorting, cracking or buckling of the plastic. Also, plastic items made to close tolerances may vary much with temperature changes. At one plant they were thrown out of tolerance by temperature changes between morning and afternoon in the shop where machined.

Problems involving the application of transparent plastics are closely associated with heat resistance. There is no commercial transparent plastic that will withstand temperatures over 100 C. Before specifying a transparent material, the designer should anticipate effect of sunlight and weathering, chemicals, fumes, abrasives and mechanical stresses.

—W. S. Larson. *Product Engineering*, Vol. 15, Sept. 1944, pp. 605-607.

Using Steel Heat-Treat Properties

Condensed from "Machine Design"

Most prominent of the heat-treat developments to reach the commercial stage are (1) induction and flame heating; (2) isothermal heat treating; (3) improved quenching; (4) shot blasting, etc.; and (5) controlled atmospheres. Strictly wartime developments might be limited to the use of multiple lower alloy steels to replace steels of higher alloy steels to replace steels of higher alloy contents, and water quenching of alloy steel armament.

To the designer, the principal advantage of induction heating lies in its application to localized zones. This makes possible the designing of parts practically free from distortion due to hardening.

Isothermal heat treating was not fully developed until the advent of constant temperature transformation curves of Bain and Davenport. This method of heat treating was limited to small sections of carbon and low alloy steels.

Allowances usually are made for distortion in designing heat treated parts by increased size or extra processing. This is especially true in gear tooth design when allowance is made for tooth "movement" in heat treating by extra length of tooth face and heavier tooth.

An important contribution to heat treating was made by Shepherd, who determined that molten salts of certain types would cool at about the same rate as quenching oil. This permits their use in cooling oil-hardening steels fast enough to insure their getting past the knee on the "S" curve untransformed. This is known as martempering.

With martempering, much of the allowance made for distortion in heat treatment can be eliminated. Combinations of martempering, induction heating, or induction softening will permit designs now considered impractical. The martempering cycle is especially suitable to the higher alloy steels, and can be combined with short cycle tempering baths to give maximum properties, minimum distortion and internal stresses.

In many applications, low strength decarburized surface is the controlling factor in the performance of the part. For this reason, the use of controlled atmosphere furnaces has increased in the past few years.

In many cases decrease in size, resulting from machining off the decarburized surface zone, would be accompanied by improvement in performance.

To take full advantage of improvements in control developed in heat treating, and the new knowledge available of hardenability and time-temperature transformation characteristics, it is necessary for the designer, the metallurgical engineer and the operating department to cooperate in removing some factor of uncertainty, at present too common.

There is some difference of opinion as to the relative qualities of case-hardened and induction-hardened parts. Initial compression stresses introduced by case-hardening are somewhat greater, and the better wear resistance due to higher carbide concentration in the case may be the deciding factor. In any event, the trend to increase the application of induction and flame heating promises to continue and will affect the layout of heat treating plants of the future.

—Harry W. McQuaid. *Machine Design*, Vol. 16, Aug. 1944, pp. 107-112.

Hardened Lead Bearing Metals

Condensed from "Zeitschrift für Metallkunde"

The most satisfactory of bearing metals on a lead basis and containing no strategic constituents is the Bn-metal, an alloy of lead with 0.69 Ca, 0.62 Na, 0.04 Li, and about 0.02% Al; it is used particularly for axle bearings in vehicles on rails. The only disadvantage is that it loses its hardness under the effect of elevated temperatures of long duration and the burning-out of the hardening alkali and earth-alkali constituents.

An attempt was made to find the reasons for this hardness instability and to modify the composition in such manner to suppress the instability in the temperature range of operation. The hardness instability was found to be due to structural changes brought about by an oversaturation with sodium in the lead basic solid solution which is higher than so far realized.

The new, modified alloys now contain: MGS 7422, 0.7 Ca, 0.4 Ba, 0.2 Na, 0.02 Li, about 0.02% Al; MGS 7420, 0.7 Ca, 0.4 Ba, 0.2 Na, 0.04 Mg, about 0.02% Al.

The reduction to 0.2% sodium and of lithium content has practically suppressed the dehardening, and also reduced the burning-out. The reduction of the lithium content has also been accompanied by a somewhat lower castability, which can, however, be counteracted by an increase in the chill-mold temperature. The resistance to corrosion has not been lowered by the reduction of sodium and lithium and the addition of magnesium.

—E. Schmid. *Z. Metallkunde*, Vol. 35, Apr. 1943, pp. 85-92.

Plywood Box Cars

Condensed from "Railway Age"

One thousand 50-ton, 40 ft.-6 in. box cars are now being constructed by the Great Northern at company shops, using plywood for outside sheathing, side and end lining and ceiling insulation. Plywood is also used in composite doors on 600 cars.

These cars are for use chiefly in shipping lumber, newsprint and other high-class heavy commodities. Hence, strength and ruggedness in construction have been secured at some sacrifice in potential weight saving. With an average weight of 45,700 lb. and capacity of 3,727 cu. ft., the weight:capacity ratio is about 12.26 lb. per cu. ft.

The plywood used for sheathing, side and end lining and doors is Douglas fir, ⅝ in., five-ply exterior grade (waterproof), sound on one side. The ceiling insulation is ¼-in. three-ply. All panels are furnished cut to exact size.

The panels, except ceiling, are first dipped in a special clear sealer and surface hardener, made up of a penetrating oil containing suitable gums. It protects back surfaces against decay and forms a binder for the wood grain on exposed surfaces, which also serves as an excellent foundation for subsequent paint coatings.

There is a good edge penetration. To the bottom edges of the sheathing is also applied a heavy coating of car cement. After application of the panels, the exterior is given a coating of iron oxide primer, followed by two coats of orange enamel, the Great Northern standard shade.

The waterproof sealer on the lining protects the back face from decay and gives a tough base for the varnish on the entire interior, including the floors. A general nailing plan was developed with cup-washered bolts through siding at the side sill.

The siding panels are butt-jointed on the side post nailers. This permits a slight movement between adjacent panels sufficient to prevent breakage of nails or tearing of the plywood at the edges.

At the butt joints a metal nailing strip, punched for nailing with a V-shaped raised ridge down the center, is used. The V-grooves are filled with car cement. A special heavily galvanized oval head nail was designed for all exterior plywood nailing.

—*Railway Age*, Vol. 117, Aug. 5, 1944, pp. 227-230.

New Non-Metallic Material

A Composite

Recent applications of a series of organo-silicon compounds called silicones have given to industry a new group of polymeric materials. They are finding application as electrical insulation, as hydraulic fluids, as pump packing impregnants for use in handling hot liquids, as waterproofing materials for paper, textiles, and other materials in the treatment of ceramics to reduce surface conductivity, as chemically-resistant lubricants, and many others.

Lying between glass and organic plastics, the silicones were first introduced to industry in a search for a varnish for glass fiber that would withstand heat. Corning Glass Works enlisted the aid of Dow Chemical Co. to produce these interesting materials.

General Electric also investigated the compounds, and produced "Dri-Film," a waterproofing material for use on cloth, paper, ceramics, and other materials. Other workers noted their possibilities for preparing synthetic resins, film-forming materials, and electro-insulation materials.

While the raw materials are cheap—sand, brine, coal and oil—the synthesis is at present expensive. Alternate methods are now being studied.

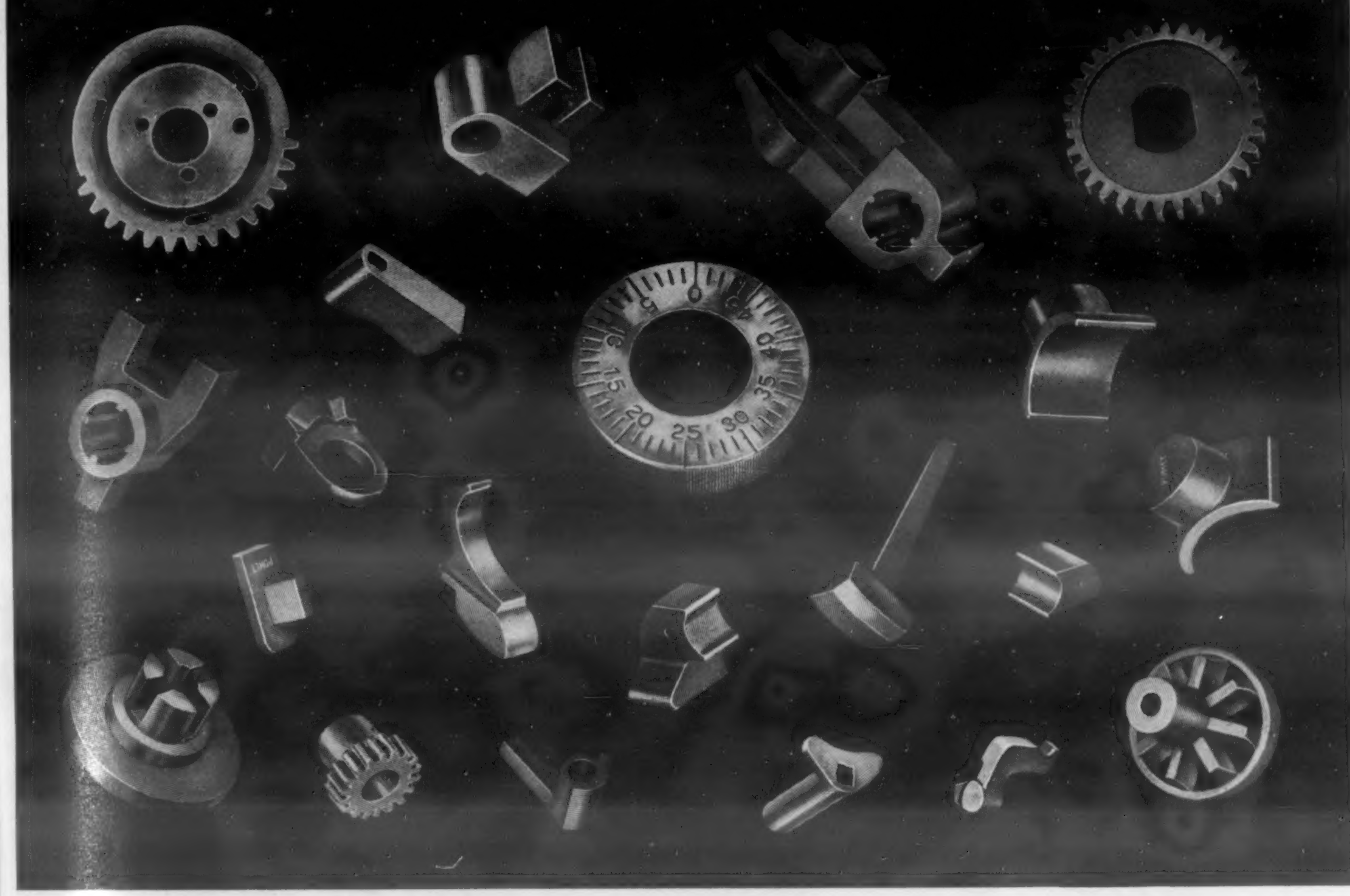
The silicones have found a war application in the aviation industry also, where they are used for damping aircraft instruments. They show a low rate of viscosity change over a wide range of temperatures.

The fluids are colorless, transparent and oxidation-resistant, and have no solvent or swelling action upon organic plastics, natural or synthetic rubber, even at high temperature. They are insoluble in water and non-corrosive to metals.

Two general classes of liquids are now in production at Dow Chemical Co. The type "200" liquids have relatively high viscosity, flash points of from 600 to 640 F., specific gravities of 0.968 to 0.973, and good dielectric qualities. They show good lubricity under light loads. Type "500" fluids have lower viscosities, boiling points from 99.5 C. up to liquids undistillable at 250 C. even under vacuum, flash points from 70 F. to 475 F., and relatively stable viscosity.

Resins show exceptional heat stability, resistance to moisture, and freedom from carbonization at high operating temperatures. A dark-colored varnish, 993 resin, is used for impregnating motor stators, transformer coils, for varnishing covered magnet wire, Fiberglas, mica and asbestos cloths, etc. It resists 175 to 200 C., even under extreme humidity. A thermosetting

POMET POWDER METALLURGY



SOME THOUGHTS ON SPEEDY RECONVERSION

When the time comes for a quick switch to peacetime products, there is much to be learned from the way in which certain manufacturers converted to war work.

Many of these manufacturers came to Pomet for parts. They found that Pomet Powder Metallurgy broke bottlenecks and cut down production time by giving them small parts in hitherto unheard of quantities—small parts of intricate design and high density that were pressed to close tolerances with little or no machining required.

With a rich background of wartime experience, Pomet is in an even better position to help manufacturers change over quickly. You will find Pomet Powder Metallurgy particularly economical in quantities of 100,000 and over. Pomet engineers will be glad to consult with you and help you now with your postwar plans. Send for literature.

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varnish, 2052, may be used for rotating equipment.

Greases constitute a third group. They are used for valves on chemical equipment and for high and low temperature lubrication.

—*Chemical Industries*, Vol. 56, Aug. 1944, pp. 222-223; *Aero Digest*, Vol. 46, Aug. 15, 1944, pp. 106, 138.

Wrought Aluminum Alloys

Condensed from "Zeitschrift für Metallkunde"

Recent investigations of the mechanical properties of sheets of aluminum-copper-magnesium alloys with about 2% Cu have shown that two alloys are possibilities to replace high-strength steels, namely, Alloy I, with 2 Cu, 0.7 Mn, 0.9 Mg, 1% Si, and Alloy II, with 2 Cu, 0.7 Mn, 1.4 Mg, 0.8% Si.

Alloy I is a typical hot-precipitation-hardening material with an elastic limit that reaches at annealing temperatures of 160 C. (320 F.) and higher, very high values after a short time, but with considerably decreasing elongation. Alloy II has a slower hot-precipitation hardening, with less steep increase of elastic limit and drop of elongation.

The maximum values of elastic limit of about 36 kg. per sq. mm. (51,200 p.s.i.) and ultimate strength of about 42 kg. per sq. mm. (60,000 p.s.i.) can be obtained either by annealing for 24 hr. at 160 to 170 C. (320 to 340 F.), or for 5 hr. at 160 to 190 C. (320 to 375 F.). Deformability in this state is still good in spite of the high ratio of elastic limit to ultimate strength.

Elongation drops from about 21 to 22% in the unhardened state to about 9 to 11% in the hardened condition.

—K. L. Dreyer & M. Hansen. *Z. Metallkunde*, Vol. 35, July 1943, pp. 137-146.

Air-Expanded Plastic Rivets

Condensed from "The Iron Age"

Similar in principle to explosive rivets, a plastic rivet has been developed that is hollow nearly to the bottom of the rivet and that is expanded with a few pounds of compressed air when it is in place, thus making a tight fit.

This preheated hollow plastic rivet will attach fabric to metal, wood or plastic. Other possible applications are to attach plastic to fabric, rubber to plastic, or plastic to metal.

The new rivet was recently developed by S. H. Phillips, process engineer, Douglas Aircraft Co., El Segundo, Cal. In design, the rivet shank and head are not limited to specific shapes, but provision must be made for center-boring through the head for compressed air application during clinching.

Just prior to driving, the rivet is heated to soften the plastic. The compressed air

forces the shank section to expand, this soft plastic section hardening immediately.

After some dozen plastics were experimented with, acrylic was most suitable, one of its good features being "plastic memory," or ability to regain its original shape upon subsequent heating. Application of heat will cause the expanded end of the rivet to shrink to its original size so that the rivet may be removed from the hole intact and capable of reuse.

Where used to fasten airplane fabric to a trussed aluminum rib, a load of 49.3 lb. was necessary to cause failure—but it was the fabric, not the rivet, that failed. Installed in a tensile jig, the rivet showed an average breaking strain of 220 lb.

Electroplated plastic rivets developed greater tensile strength, flexural strength and dimensional stability than the unplated variety. Crazing of the plated rivet occurs on the expanded end, but all visible portions of the rivet are entirely unaffected by the driving process.

—*Iron Age*, Vol. 154, July 27, 1944, pp. 52-53.

Cracks in Rail Flanges

Condensed from "Stahl und Eisen"

Origin and effects of cracks in rail flanges were investigated by statistical methods according to time of service of the rail, manufacture and type of track. In general, the sole of the flange contains more or less conspicuous and numerous irregularities in the crystalline structure, which are distributed over the whole length of the rail, but these irregularities lead to fracture only if a crack, even a fine one, has been caused by other circumstances, *e.g.* by straightening. Of special importance are the blisters occurring at the edge of the flange.

Flange cracks are determined by static and dynamic methods, of which the bending test is the preferred one. In the bending test, a higher deflection corresponds to a higher load at fracture. No great differences were found between rails of converter steel and of open-hearth steel.

The appearance of the fractured area obtained in threshold tensile tests show that the fracture in cracked rail sections starts from an already existing more or less deep crack, while in sound rail sections the fracture starts from a point, mostly from a tiny surface injury or material defect, which acts as a notch.

The threshold tensile strength in cracked rail sections was 4.5 tons in good rails 10.5 tons; the average bending deflection was 2.7 and 8.9 mm., respectively, and the average load at fracture 27 and 42.7 tons.

Both statistical and testing results show clearly that rolling and straightening of the rail have a determining influence on the formation of the rail flange and thus on the tendency to flange cracks. Differences in manufacturing methods were recommended for further investigation, especially of the question as to whether silicized rails would improve the resistance to flange cracks.

—R. Kühnel. *Stahl u. Eisen*, Vol. 64, Mar. 16, 1944, pp. 169-175.

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5 Testing, Inspection and Control

Specifications • Physical and Mechanical Property Testing and Inspection • Routine Control and Instrumentation • Radiography and Magnetic Inspection, Spectrographic and Photoelastic Analysis • Corrosion- and Wear-Testing • Examination of Coatings • Surface Measurements • Metallographic Inspection and Technique

CONTENTS

Variables Affecting Impact Tests

Condensed from "Metals Technology"

A great deal of work has been done on the notched-bar impact test. The many factors that may control the test results have been pointed out repeatedly. The importance of the effect of type and dimensions of the specimen as well as of testing temperature has been recognized.

The present discussion is an outgrowth of an investigation of the quality of a number of weldable plain carbon and low alloy steel plates. Most of the specimens were standard keyhole or V-notched Charpy specimens with modifications of breadth.

Doubling the breadth of a standard 10-mm. notched-bar impact specimen broken at room temperature causes a decrease in the specific energy absorption for most of the steels studied. However, in the tougher, and more ductile steels, the narrow specimens have a lower specific energy absorption.

The impact value decreases as the sharpness of the notch increases. The sharper notch causes a greater tendency for brittle failure, whereas an increase in the radius of the notch gives greater deformation with less tendency towards brittle behavior. The V-notched Charpy test specimen is preferred to the keyhole-notched specimen for the steels studied, since the sensitivity of the test is increased and the test specimen is strained as a simple beam.

Testing temperature is one of the important variables affecting the impact value. For specimens tested at various temperatures, the effect of breadth is greatest for the steel studied (mild steel) in the range of temperatures from just above to below room temperature. It is difficult to obtain reproducible values with the V-notched bar specimens when tests are made in the transition zone; when the less sensitive keyhole-notched specimen is used, consistent values are found even in this zone.

In general, the energy absorption in the slow bend and in impact loading are in good agreement for homogeneous steels. However, a decided increase in energy absorption in the impact compared with the slow-bend method was noted in a number of commercial-quality non-homogeneous materials containing laminations or having fibrous breaks.

A linear relation between energy absorption and work-hardening has been found under a variety of test conditions for two plain carbon steels. Other types of steels will undoubtedly show a similar relationship, although the slope of the curve will vary. It is possible that this relationship is a fundamental constant for each steel, which would be useful in the general solution of the behavior of mechanical test specimens.

—C. E. Jackson, M. A. Pugacz & F. S. McKenna. *Metals Technology*, Vol. 11, Aug. 1944, T. P. No. 1668, 17 pp.

Modern Welding X-Ray Inspection

Condensed from "Industry and Welding"

The recent advent of the million-volt X-ray machine has led to inspection over a greater range of thickness than had ever before been possible, and speeded up the inspection of heavy steel welds and castings. With this machine, in certain types of inspection, magnesium alloy castings, ¼ to 12 in. thick, can be examined with one exposure, whereas with lower-powered units as many as 15 separate exposures were necessary.

The most popular units are in the 140 to 250 kv. range. Welds up to two in. thick can be satisfactorily inspected at 250 kv., while light-alloy castings can best be inspected at 140 kv. The principal difference in X-ray technique when applicable to the lighter alloys is concerned with power output.

A good X-ray technique should be standardized on the most satisfactory film for the material to be encountered in the inspection, together with proper kilovoltage, exposure factors, and focus-to-film distance that will reduce distortion and render a good sensitivity. Where thickness varies over the entire range of inspection, a penetrameter sensitivity of not less than 2% should be recorded on the film.

Metallic filters interposed between the

X-ray tube and specimen will improve sensitivity over a wide range and will reduce the number of exposures required on a given specimen.

X-ray inspection of spot welds is now recognized as the only practical means of inspecting these thin sections without destruction. For inspection of steel, aluminum and magnesium spot welds, very low voltages ranging from 40 kv. down to 12 kv. are necessary to depict with clarity the fine voids that might be present.

Exposure factors and film must be chosen with great care. It is advantageous to have an X-ray tube equipped with a beryllium metal window and a tungsten target to allow passage of the longer wave-lengths and afford better film contrast. This is contrary to techniques employed on other types of welds.

Low-powered machines can render a good sensitivity with thicker specimens than those for which they are ideal, by proper changes in technique. For example, calcium tungstate intensifying screens afford a means of penetrating thick sections with low-powered units by assisting the X-rays in forming the image. An X-ray film placed between two such intensifying screens at as low as 95 kv. will make possible the rendition of an image of a 3/8-in. stainless steel weld.

—Robert Taylor. *Industry & Welding*, Vol. 17, Aug. 1944, pp. 68, 70, 72, 99-102.

Metallographic Quality Test

Condensed from "Transactions" of the American Foundrymen's Association

The term "malleable iron" here refers to the type of iron covered by A.S.T.M. Specification A-47-33, Grade 35018. The quality of this iron is adversely affected by the presence of one or more of the microconstituents: primary graphite, pearlite and primary cementite.

Primary graphite consists of flake graphite that forms during solidification. It has a deleterious effect on strength, ductility and shock resistance. Once formed, it cannot be eliminated. Pearlite is the result of failure of the iron to respond to the annealing treatment. It impairs ductility, shock resistance and machinability.

Primary cementite, also the result of unsuccessful annealing, is extremely hard. It dulls the cutting tool and reduces the ductility and shock resistance of the iron. Both pearlite and primary cementite can be eliminated by reannealing.

Examination of the microstructure of tensile test specimens containing primary graphite has proved that the amount and distribution of this constituent is closely related to the strength and ductility of the metal. Photomicrographs of the structures of malleable iron containing primary graphite, therefore, may be used as standards for rating other irons. The same specimen may be examined for primary cementite and rated with standard photomicrographs. The amount of pearlite is expressed as a percentage of the specimen area.

In selecting the location in a casting from which the sample is to be taken, sections subjected to high stress and relative solidification rates must be considered. Primary graphite is usually found where solidification is slowest.

Sampling is facilitated by the use of a small core drill, which permits sampling without impairing the casting. A diameter of 3/16 in. for the sample is satisfactory.

The samples are mounted in plastic and polished metallographically. Examination is made with a binocular microscope at a magnification of 8 diam. After determination of the primary graphite rating, the specimen is lightly etched in nital and examined at 100 diam. for primary cementite. Given a deeper etch, the same specimen may be examined for pearlite, usually at a magnification of 100 diam.

—C. T. Eakin & H. W. Lownie. *Trans., Am. Foundrymen's Assn.*, Vol. 52, Sept. 1944, pp. 261-270.

Inspecting Magnesium Alloy Castings

Condensed from "The Iron Age"

Supplementing of metallographic studies to X-ray inspection seems indicated in certain classes of magnesium alloy castings, as a means for more accurate interpretation of what actually exists in a given specimen.

In X-ray inspection, a great deal depends on the quality of the negative as affected by technique chosen, fineness in grain structure of the film used, and the general experience of the inspector. Certain facts indicate that even the highest quality radiograph is rather inadequate for absolute accuracy.

Magnesium casting alloys having the best structure frequently develop a type of defect known as micro-shrinkage—centerline weakness or interdendritic piping appearing as small cavities between individual grains. Numerous magnesium alloys, although having lower than average value for solidification shrinkage, have a wide range of temperature over which solidification takes place.

As an aid to speedy fabrication, and to establish uniform standard for accurate subsurface inspection, a study was carried out on sand castings rejected by X-ray inspection. Castings represented a group of returns.

Having determined that micro-shrinkage existed, specimens were tested mechanically, then examined metallographically. This examination showed numerous cavities between individual grains. None of the fissures was continuous.

Conclusions reached were: (1) Radiographic interpretation rejecting castings as possessing stress cracks was erroneous; (2) critical area was relatively sound, since stress-raising defect would cause early failure; minimum micro-shrinkage interfered in no way with serviceability; (3) accurate typing of defects by metallographic examination was accomplished.

—Robert Taylor. *Iron Age*, Vol. 154, July 13, 1944, pp. 55-58.


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books

FOR METALLURGICAL ENGINEERS

Machine Members

DESIGN OF MACHINE MEMBERS. *By Alex Vallance & V. L. Doughtis. Published by McGraw-Hill Book Co., New York, 1943. Cloth, 5¼ x 8½ in., 559 pages. Price $4.00.*

The authors of this book have had many years experience in teaching machine design, and one of them is now chief designer for a large manufacturing firm. This is the second edition of the book, which is planned and written as a text book for students in mechanical engineering.

The authors state: "No attempt has been made to make this book a reference handbook for machine designers." Several hundred problems for assigned work are given following the text of the book.

Throughout the book there is maintained a balance between derivations of formulas to give the student familiarity with the kind of analytical methods used in machine design, a summary of the mechanics of stress and strain, data concerning the strength and ductility properties of materials, and a discussion of the principles involved in assigning safe working stresses for machine members.

Then there are some 18 chapters, each one of which treats of the special problems of one type of machine member. There is a chapter on shafts, one on bolts and screws, one on brakes, one on gears, one on belts, and so on. The chapters on sliding bearings and on ball and roller bearings aroused the reviewer's especial interest.

In this second edition, some rearrangement of the order of chapters has been made, and considerable new material has been added, especially data on non-ferrous metals, and on plastics and synthetic rubber-like materials.

This is a textbook rather than a handbook, but it is the kind of a textbook a student will wish to keep after he is graduated. It is also a book that will make a valuable addition to the working library of any machine designer.

—H. F. MOORE

Using the Spectroscope

EXPERIMENTAL SPECTROSCOPY. *By Ralph A. Sawyer. Published by Prentice-Hall, Inc., New York, 1944. Cloth, 6 by 9¼ in., 323 pages. Price $5.00.*

Intended as a practical guide for the student of spectroscopy and for the research worker who must use those methods occasionally, Dr. Sawyer's book omits those pages of mathematical formulae and derivations which make the usual text so formidable to the beginner. Emphasis is placed upon to-the-point instructions in adjusting the instrument and actually putting it to use.

While the scope of the text is limited to emission spectroscopy and absorption spectra are merely mentioned, these limitations will not reduce the book's value to the spectroscopist in the metal industries. After a brief discussion of the history of the subject, the author outlines the general principles of the spectroscope, construction of the instrument, and the care and adjustment of its parts. Methods of determining the wave length of the spectral bands, and of determining their intensity for quantitative work, are given in a manner calculated to be of practical assistance to the technician faced with the necessity of obtaining usable data.

A chapter upon photographic methods is included for the benefit of the worker not familiar with them, and chapters upon infrared and ultraviolet technique will provide an introduction to those fields. A section upon spectrochemical analysis should be very welcome to the laboratory man who is, after all, primarily concerned with putting the spectroscope to just this use.

—KENNETH ROSE

Metal Forming

METAL FORMING BY FLEXIBLE TOOLS. *By Chris J. Frey & Stanley S. Kogut. Published by Pitman Publishing Corp., New York, 1943. Leather, 6 x 9¼ in., 193 pages. Price $3.00.*

Chris J. Frey and Stanley S. Kogut have put on record in this book valuable methods evolved in United States warplane manufacture. The need for diversified production methods is well stated.

The use of large hydraulic presses, with confined rubber forming pads and cheaply produced male die members, for forming aluminum alloy sheet material, is thoroughly and clearly presented with ample illustration and data for calculation.

Next, the use of drop hammers with cast zinc alloy dies, for the deeper forming and drawing of aluminum alloys, is well recorded, particularly as to the methods of making such dies.

The reviewer personally has found it rather hard to accept the relatively costly use of relatively inexpensive drop hammers for many of the operations involved, but certainly they have played a vital part in the war effort, and their utility should be acknowledged. Perhaps the authors will add in a later edition some discussion of the growing use of similar soft low cost dies in double action hydraulic presses, which, however, are definitely not inexpensive.

The final chapter on brake dies for bending operations is quite proper to include in the "flexible tool" picture.

The book is worthy of a place in the reference libraries of pressed metal engineers and technicians.

—E. V. CRANE

Other New Books

MANGANESE IN CALIFORNIA — BULLETIN NO. 125. *Published by State Division of Mines, San Francisco, Calif., 1943. Cloth, 6¼ x 9¼ in., 387 pages. Free to those interested.* The purpose of this publication is to assemble data and sources of data on all noteworthy deposits of manganese in California; to discuss their utilization, history and the place these deposits occupy in the whole manganese industry; and to discuss the characteristics, origin and geology of these deposits, which occur particularly in the State of California. Several authors have shared in the undertaking.

SYMPOSIUM ON THE SIGNIFICANCE OF THE HARDNESS TEST OF METALS IN RELATION TO DESIGN. *Published by the American Society for Testing Materials, Philadelphia, Pa.,* 1944. *Paper* 9 x 6 *in.,* 58 *pages. Price* 75c. This symposium includes notes on the indentation hardness test, with conversion tables and a brief bibliography. It includes also technical papers on present types of hardness tests; on fundamentals of hardness testing, followed by discussions by authorities; and finally, the tentative hardness conversion tables for steel showing the relationship between diamond pyramid hardness, Rockwell and Brinell values, A.S.T.M. designations: E48. The authors are all generally recognized authorities.

METALLURGICAL ENGINEERING news

Equipment • *Finishes* • *Materials* • *Methods* • *Processes* • *Products*
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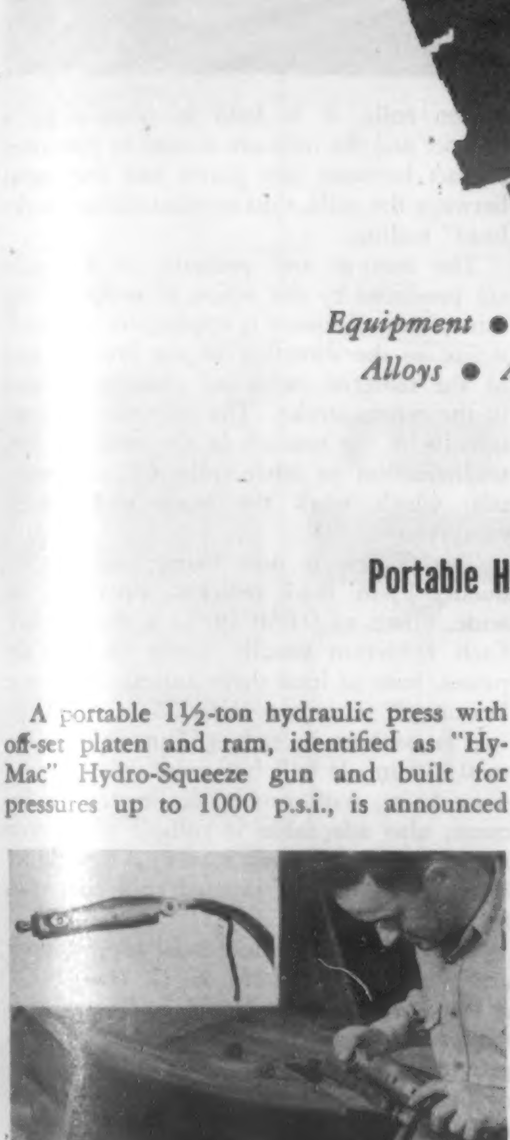
Portable Hydraulic Press

A portable 1½-ton hydraulic press with off-set platen and ram, identified as "Hy-Mac" Hydro-Squeeze gun and built for pressures up to 1000 p.s.i., is announced



by *Hydraulic Machinery, Inc.*, 12825 Ford Road, Dearborn, Mich. "C" ring-type seals are used on the piston. The ball-type switches are conveniently located on the unit to control a spring returned four-way valve.

As long as both switch buttons are pressed, the valve solenoid is energized and oil under pressure is valved into the gun moving the ram through the working stroke of 1½-in.

When one or both buttons are released, the valve solenoid is de-energized and the ram starts the return stroke. The off-set platen and ram are constructed to accommodate numerous special adaptors for various operations, such as pressing bushings and pins, riveting, dimpling, etc. This gun will reach any hard-to-get-at places, formerly inaccessible to power tools.

A standard Hy-mac hydraulic power unit, complete with pump, motor, tank and valves, generates the hydraulic power for operation of the gun. Power units can be furnished with sufficient capacity for powering numerous guns from a single unit. High pressure hydraulic hose connects the guns to the power unit.

Template Photographs on Steel

A few years ago it would have taken 100 man-hours to reproduce a single template for the B-29 Superfortress. Now templates are produced at *Boeing Aircraft Co.* in a few minutes by putting "photographs" of the designs on "Armco" galvanized "paintgrip" steel sheets with a special mill-Bonderized coating. The templates are distributed to hundreds of main and sub-contractors.

The sheets, painted pale green, reproduce clean, unflaked lines when the pattern is scribed. Standard photographic processes, chemicals and equipment, including a 6-ton camera are used. The master template is set on an easel and held in place by suction.

From an adjoining room the camera takes a picture of the pattern through an aperture in the intervening wall. The negative, reduced to one-fifth, is made on glass plate to prevent shrinkages. Tolerances of no more than one-thousandth of an inch a foot are permitted.

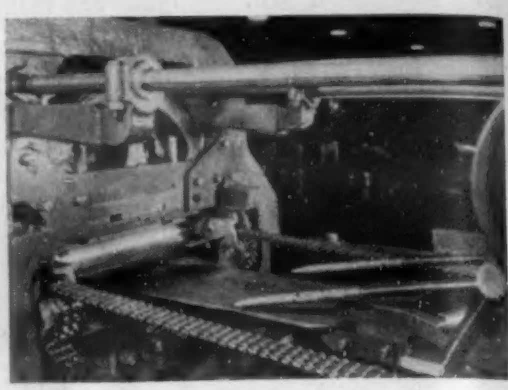
For reproductions, lacquered steel sheets on an assembly line basis are used. They are sprayed with a photographic emulsion. The sheet is placed on the camera easel in the dark room while the negative glass plate is placed in the camera and "shot" through the lens, projecting the pattern on the "Paintgrip" sheet. It is developed in the regular photographic way.

Usually the sheets are made to the actual size of the B-29 parts. The templates serve as jigs and fixtures, patterns for router and drill operators, and in producing various dies. A carload of these sheets is used by Boeing every two weeks. The steel sheets are furnished by *American Rolling Mill Co.*, Middletown, Ohio. Extensive post-war uses are envisioned.

• Tool steels are now being cast-to-shape for commercial applications by *Jessop Steel Co.*, Washington, Pa. They are used for dies, forming tools, glass molds, gages, hobs, gears, cams, etc. They are cast in air hardening, oil hardening, flame hardening, stainless and heat resistant analyses.

Rolling Mill of Radical Design

Rolling mills for both ferrous and nonferrous metals that embody a distinctly new rolling principle have been invented by Frank R. Krause and developed by engineers of the *Lewis Foundry & Machine Div., Blaw-Knox Co.*, Pittsburgh. Instead of the material passing through power



driven rolls, it is held in tension by a grippet and the rolls are moved by frictional contact between cam plates and the metal between the rolls, thus approximating "turks head" rolling.

The motion and pressure of the rolls are produced by the action of reciprocating cam plates. Pressure is applied on the work stroke in the direction of the finished end of the material, with no pressure applied in the return stroke. The reduction is done largely by the tension in the strip in contradistinction to other roller-forging methods, which work the stock under high compression.

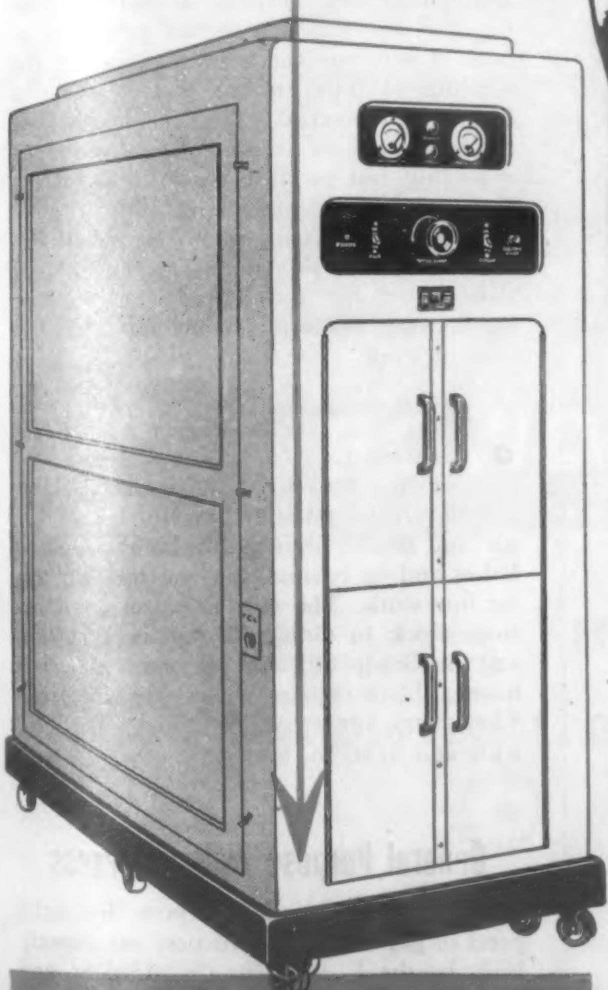
The process is now being used for reducing ½-in. thick material, up to 26 in. wide, down to 0.030 in. in a single pass. Such reduction usually needs four to six passes, with at least three anneals for brass. It can roll to as low as 0.005 in. to 0.010 in., as well as to reduce 1-in. thick slabs to 0.050 in. It will hot reduce slabs up to 4 or 5 in., with proper designated equipment; also adaptable is rolling of tapered material such as spring leaves. A possibility is the formation of tapered skin coverings for aircraft wings.

The first two commercial applications are at the plants of the *C. G. Hussey Co.* at Pittsburgh and the *Michigan Div., Revere Copper & Brass Co.* at Detroit. The mills provide a solution to the rolling problem of being able to exert great pressure with rolls of small diameter (4 in. in diam. and 28 in. long of hi-carbon, hi-chrome steel forgings). The use of back up rolls provided one solution of this in wide strip mills, but the rolls in 4-high mills still suffered because they are supported by bearings at the roll necks and distortion at great rolling pressures was inevitable.

In the Krause mills, no pressure is placed on the roll necks other than necessary to keep them in position, with only plain bronze bearings being provided. The cam plates are heat treated alloy steel forgings. The entire pressure is distributed evenly along the faces of the rolls by cam plates, which, with the backing up structure of the housing, can be made as massive as is necessary. At the Hussey plant, which is described throughout this article since it is typical, the housing, cam plates and reciprocating parts weigh ten tons.

(Continued on page 1432)

There's no ONE-MAN-BAND in Electronic Heating



Although it is possible to construct an electronic heater that will generate a great range of high frequency currents, it will not perform *all* heating jobs efficiently and it would be very costly in use.

Virtually every application of electronic heating requires a specific FREQUENCY AND POWER combination. Therefore, to realize the maximum advantages of this improved heating method, *each installation should be designed and built for its particular application.* For example: when a heating operation can best be done at 5 kw and 22 megacycles it would be *wasteful* and *inefficient* to use a machine that delivers 20 kw at 500 kc.

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119 Monroe Street Garfield, New Jersey

Manufacturers of Vacuum Tube and Spark Gap Converters since 1921

Wedges, with indicators graduated at 0.001 in., located between cam plates and plates on the mill housing, provide for adjustments and can be made to give the effect of a crowned roll. Reciprocation is done by a motor directly connected to a crank drive, with connecting rods mounted on crank pins integral with the gears and cross heads directly connected to the mill housing. The stroke may be either 36 or 32 in. long. Coolant from an 800-gal. tank is sprayed on the rolls at 30 gal. per min.

The peak load is 150 to 175 h.p. for 16-in. width material, equivalent to 10 h.p. to each inch of width. Gripper jaws are pneumatically operated and return rapidly to their original position. After being rolled, the material goes to a blocker or reel, handling a maximum coil 20 in. in diam.

Strip rolled by the Krause method shows a finer and more even grain structure than is secured by conventional rolling practices. Olsen cup tests show no variation from strip rolled by other methods. In conventional rolling, copper sometimes cracks along the edges 1½ in., but maximum on Krause mills is ¼ in., averaging less.

Delivery speed, a maximum of 30 ft. per min., is relatively slow, but economy lies in complete reduction in one operation and without intermediate annealing, making, too, for a more compact mill installation. Lewis engineers are developing the welding of bars end to end to make a continuous process. The relatively slow delivery suggests straight line continuous annealing and pickling from the discharge end of the mill without rehandling.

The accompanying photograph includes the entry side, showing a portion of the slab as fed and the thinner portion near the housing where the reducing process has been at work.

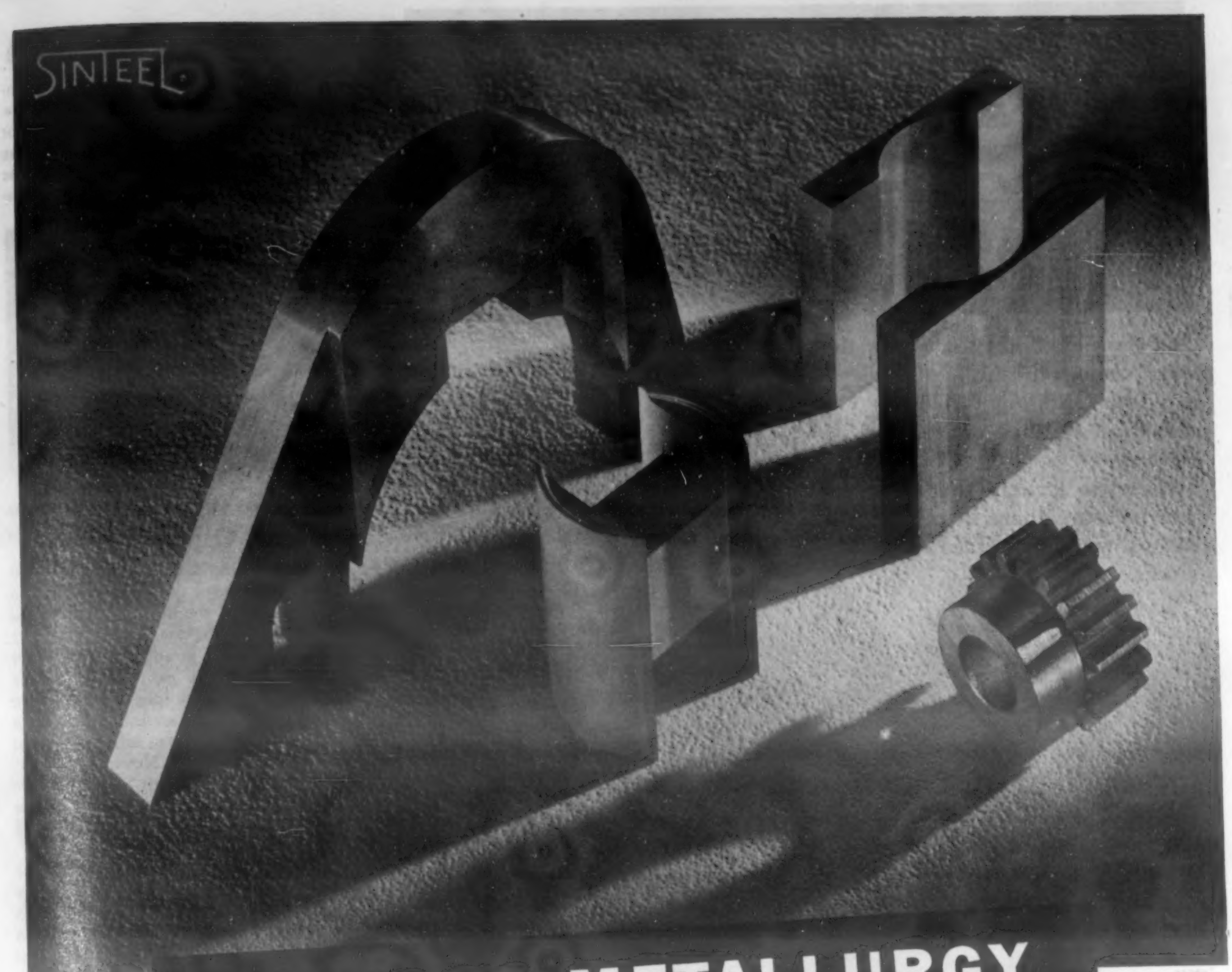
● *Carboloy Co., Inc.,* Detroit, has added a ¼-in. size tool to styles 4 and 7 right- and left-hand standard turning tools for use on small, high-speed, high precision lathes and in boring bars and tool holders for fine work. The new standards available from stock in Grade 78 for steel cutting and in Grade 883 for all other materials have a ¼-in. square shank 1½ in. long. They carry a tip 3.32 in. thick, 3/16 in. wide and 5/16 in. long.

General Purpose Hydraulic Press

A 100-ton general purpose hydraulic press of gap frame construction was recently built by the *E. W. Bliss Co.,* 53rd St. and Second Ave., Brooklyn 32. It features rugged frame construction and smooth enclosures. The slide is accurately guided by adjustable gibs.

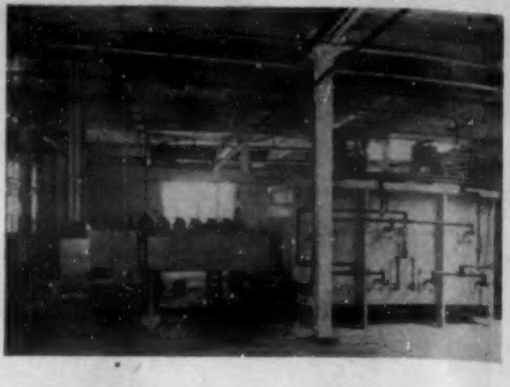
Although for manual control, the electric control used on straight side single action presses is available for automatic reverse, either by pressure or position.

For small production, the pumps are usually mounted in the frame of the press, while for high-speed production the pump is mounted on top of the frame. Modification of the bed and slide can be readily made for special purposes. Horn-type presses are also available in this series.


SINTEEL

Continuous Bright Annealing Furnace

Coils of silver solder wire are clean annealed in an open fired chamber of a new furnace without the need of muffles or external atmosphere generating units. The right atmosphere is controlled from the gas proportioning equipment, which regulates the air-gas supply to the burners. The furnace was built by *W. S. Rockwell Co.*, 50 Church St., New York.



The furnace has a continuous mesh belt conveyor that carries the solder through an entrance vestibule, the heating chamber and the cooling section, the latter two being kept filled with the atmosphere formed by the burning of the gas in the furnace chamber. Such an atmosphere is also found satisfactory for bright annealing and clean annealing of copper, brass, nickel silver and sterling silver products. However, the furnace can be equipped with an alloy muffle for bright annealing other materials that would require special atmospheres produced in an outside generator.

The alloy mash belt conveyor has a unique air cylinder take-up to keep the pressure against the belt uniform and constant and is driven from the charging end through a variable speed drive. Driving the belt from the charging end has proven to increase the length of conveyor life.

The charging and discharging end vestibules have curtains to exclude air and to keep a reasonably positive pressure within the furnace. The discharge retort is water jacketed for about a 5-ft. length, which is followed by a water spray section for fast cooling of the work prior to discharge. The heating hearth is of alundum tile, overlaid with alloy wearing strips.

The furnace is suitably refractory lined and insulated, and is fired by gas burners under and over the hearth. Two alloy 3000 C.F.M. fans in the arch circulate the atmosphere uniformly over the entire furnace capacity and its contents at a temperature of 800 to 1200 F.

The operating temperature depends on the kind of alloy to be annealed and the required speed of travel of the conveyor through the furnace. The time of work in the furnace can be set for a range of 10 to 60 min.

● A water-soluble paint stripper that loosens paint for speedy removal by hosing off with water has been developed by *Turco Products, Inc.*, 6135 S. Central Ave., Los Angeles. A clean paint-free surface is left, requiring but little after-treatment to prepare for further processing. Called "Turco Stripper L-780," it is non-corrosive on metals. It is good for removal of zinc chromate primer.

Plug-In Timers for Resistance Welders

The new improved Weltronic universal timers for resistance welder control, with interchangeable "plug in" type control panels, make possible the conversion of timing controls to any of the NEMA standard types in only a few seconds, and bring a new conception of flexibility, states the *Weltronic Co.*, 19500 W. Eight Mile Rd., Detroit 19. It permits any resistance welder to be immediately available for any type of welding within its capacity.

Use of a flexible cable, multi-point plug and receptacle for the interconnection between a control panel and the power supply unit, plus a slotted-hinge type panel mount, reduces the removal of a control panel to a simple swing-out, pull-plug, lift-off hand operation. Another panel of either the same, or for a different type of welding, can be set in just as easily.

Provision of a spare control panel to quickly replace any one of a group in service permits the inspection or servicing of all welder controls to be performed without shutting down of any of the machines. Then, too, the servicing can be done away from the production department and where proper facilities are available.

The Universal power supply unit is adaptable for 115, 230, 575, or 460 volt, 50/60 a.c. by merely shifting one jumper. The entire unit is mounted on a single panel that can be removed, for servicing, by taking out four screws.

A minimum of moving parts, fewer and less expensive tubes and interchangeable component parts, made possible by the use of exclusive Weltronic timing circuits, reduces maintenance to a minimum. Precision timing, fully electronic and adjustable by easily read dials accurately calibrated in cycles, is provided for wide ranges of welder electrode movement and pressure sequences. Each time adjustment is independent of all others.

● "Pliastic" cement is a new synthetic resin adhesive of *Paisley Products, Inc.*, 1770 Canalport Ave., Chicago 16, a soft white fluid cement, used as is, or reduced with water. It can be applied by six kinds of devices, brush to spray gun, and is suitable for binding a host of materials, including metals. When dry, it is a semitransparent, glossy, flexible coating with used as a replacement for rubber latex. excellent heat sealing properties. It is often

Two Induction Heating Innovations

A new type two-station radio frequency electronic heating machine and a new supersilent water-cooled motor generator set for use in 3000 to 9600 cycle Tocco units were shown for the first time at the National Metal Congress in Cleveland by the *Ohio Crankshaft Co.*, Cleveland.

The new electronic machine has a normal frequency of 450,000 cycles and a 20-kw.

(Continued on page 1438)

output capacity. It is the first tube type unit with two independent work stations, operated at the same or widely different frequencies. This gives versatility for brazing, hardening, annealing, soldering or heating of small parts. One-station models in the tube classification are available.

With the water-cooled motor generator, high frequency induction heating is possible

where high heat and grimy shop conditions prevail. It is hermetically sealed to keep out foreign matter.

The electronic machine is self-contained, with work pan, power units and all controls. Sub-assemblies are mounted on beds, resting on flat metal tracks, enabling the entire assembly to slide out of the cabinet. Featured are shock mounting of tubes and power contactors, while tube filament voltages automatically are held constant over a wide range of line voltage variation.

No manual adjustments are needed. Matching transformers are so located that the unusually high voltage does not come out at an exposed spot. Inductors are safely grounded.

A pistol-grip handle changes the plate voltage taps while a dial with a tap switch for the grid drive is at the rear control station. The grid bias control is on the front meter panel. The tubes, air and water-cooled, use a 3-phase line supply. The machine works on 220-440 volts.

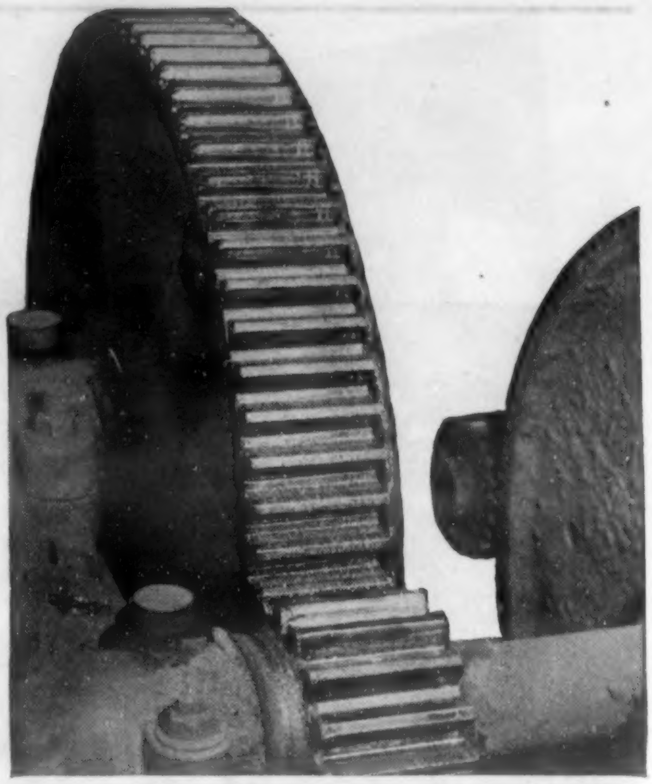
Installation means hooking up three connections: Power and the inlet and outlet water lines. Skilled operators are not essential.

Three major features are in the new generator. It is absolutely silent at full operating power; resilient mountings eliminate vibrations; foreign matter cannot enter. Within the cooling jacket are 16 channels or water and air ducts extending the full generator length, easily cleaned. Water cools even the generator bearings. Ventilation within the generator is accomplished by a blower.

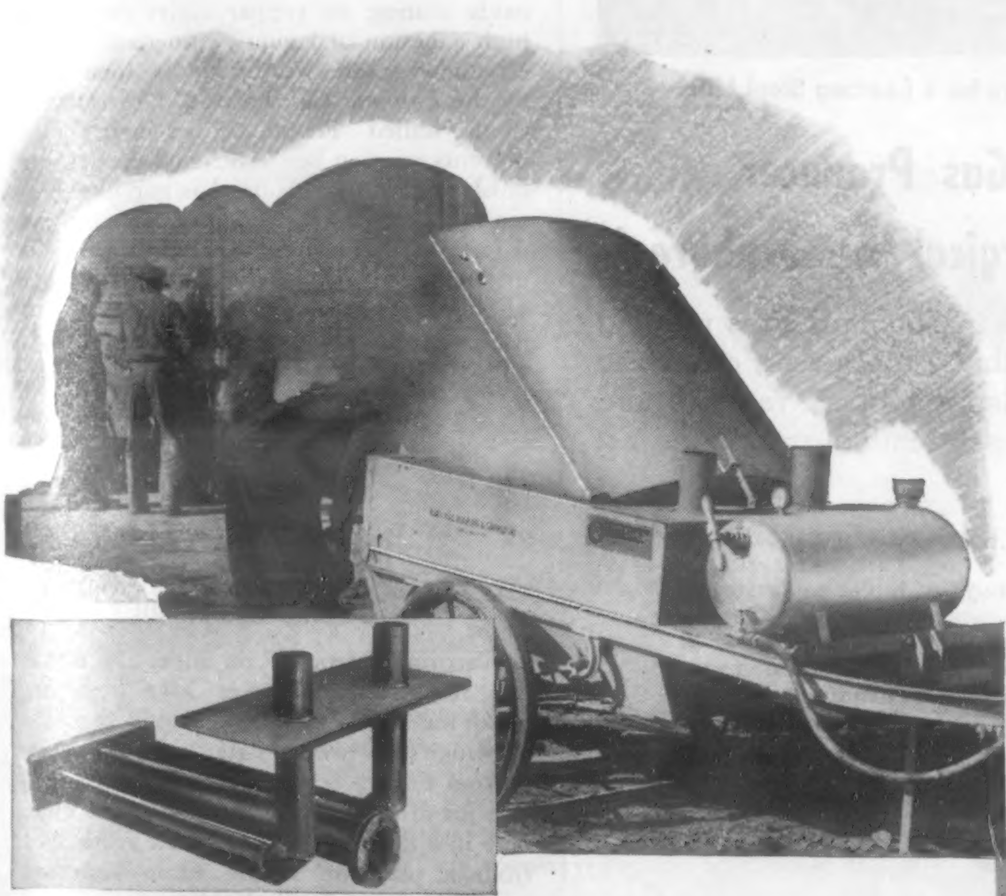
● A new slide rule and decimal point locator is announced by *Pickett & Eckel*, 53 W. Jackson Blvd., Chicago 4. It enables persons with a limited mathematical background to solve and place the decimal point up to 19 places in difficult problems, involving cube root, square root, log and trig factors. The makers claim that their new rule does four things not accomplished by other rules.

WE ANNOUNCE the recent addition to the Murex line of Type MA—the first true Grade E-7011 electrode. A general purpose rod, which handles easily in all positions, Type MA is designed primarily for A.C., but may also be used with D.C., reverse polarity. It deposits weld metal of high tensile strength and can be used on Carbon-Moly. and other 70,000 P.S.I. steels.

Further information on request.

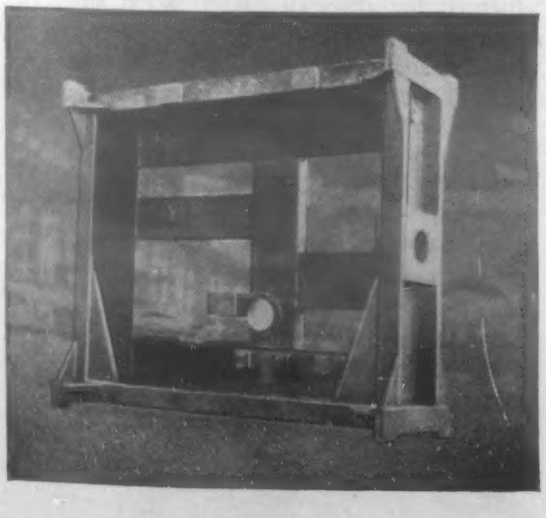


OPERATING INCHES deep in coal dust, these spur gears have been driving the mechanism for conveyor and cleaner cones since 1932. The gears are cut from Murex welded gear blanks, fabricated by Lukenweld, Inc. from rolled steel plate, which is free from blow holes, sand pockets or other internal defects sometimes found in poured blanks.



IN THE MELTING OF ASPHALT, temperatures up to 2,000°F. are generated by the heat flue system, which is welded with Murex Electrodes by Littleford Bros., Inc. The melting kettles are also fabricated with Murex and, according to the manufacturer, the welds stand up under the terrific heat "exceedingly well."

ELECTRODE RESEARCH and development work is carried on at the Metal & Thermit laboratory at Woodbridge, N. J. Raw materials, including the core wire and flux ingredients, are carefully analyzed in order to produce electrodes of certain pre-determined characteristics. Electrodes are tested for their operating and deposition characteristics and the quality of the weld metal.



THE MACHINE TOOL INDUSTRY speeds vital production through the use of arc welding. Other advantages of welded construction are ample rigidity with less weight than obtained with castings, and lower cost. The base illustrated was welded from flame-cut plates by The Dayton Fabricated Steel Co., with Murex Type FHP electrodes—"hot" downhand rods which produce sound, X-ray clean welds of high tensile strength and good appearance.

MUREX

ARC WELDING ELECTRODES

•

METAL & THERMIT CORPORATION

120 Broadway, New York 5, N. Y.

ALBANY · CHICAGO · PITTSBURGH
SOUTH SAN FRANCISCO · TORONTO

Specialists in welding for nearly forty years. Manufacturers of Murex Electrodes for arc welding, and of Thermit for repair and fabrication of heavy parts.

New Temperature Control System

A new type of Micromax electric control for electrically-heated furnaces, ovens, etc. is announced by *Leeds & Northrup Co.*, 4934 Stenton Ave., Philadelphia 44. Called the "Duration-Adjusting" type, it not only regulates electric input to hold temperature at a selected control point, or to a program, but holds so well as to promote most efficient balance among product uniformity, speed of output and flexibility of operation.

Input is either "full-on" or "full-off." It automatically controls the time during which current is on or off. It provides full proportional time action as compared with the more familiar full proportional positioning action, as well as automatic droop correction. It can be equipped with overshoot control, valuable when the furnace is coming up to temperature.

● A stable, adherent non-reactive cupric oxide coating on copper alloys that gives high adhesion of laquers, paints and enamels under severe weathering is announced by the *Enthone Co.*, Elm St., New Haven, Conn. Called "Ebonol C," its inert nature prevents reaction between it and the organic finish. The finish obtained is nap-like, presenting a relatively absorbent base for the paint to be anchored to. Alloys with 60 to 100% Cu can be treated. It is not suitable for clear lacquers, etc. because of its dark color. Operations are at 210 F., with treating time 10 min.

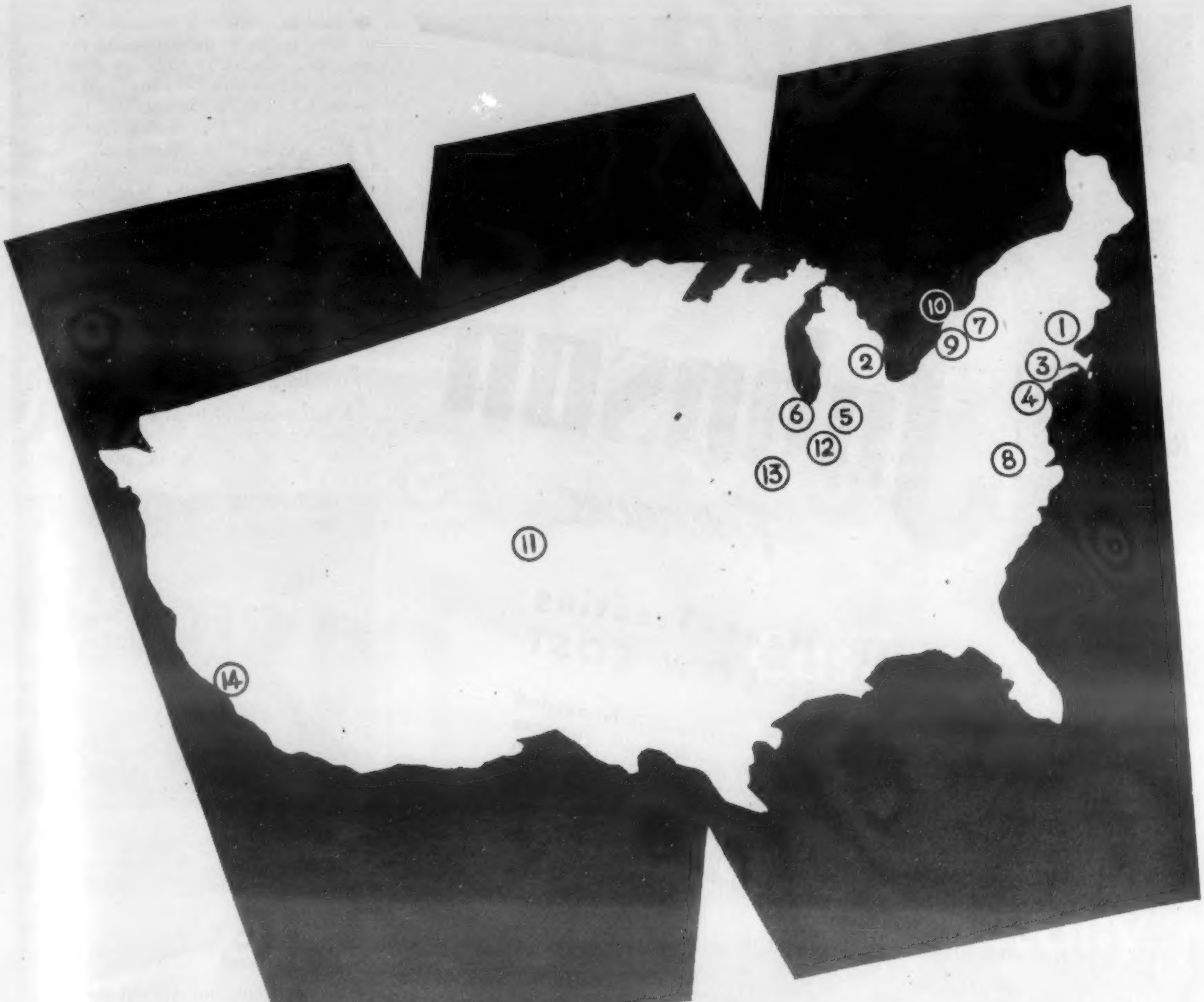
Diamond Dies for Electronic Equipment

Electronics depends on super-fine wires, and improved techniques have been devised for production of diamond dies for drawing such wires, states the *War Production Board*. Scientists have divulged details for drilling the precisely-shaped minute hole in a diamond by an electric spark shot from a platinum needle while both are immersed in a chemical solution.

Diamond dies for producing wires of spiderweb fineness will be manufactured more quickly and economically when finely reduced to commercial practices, according to Bureau of Standards scientists who performed the research under WPB auspices.

Eighteen months are needed to train polishers and drillers of small diamond dies of the best qualities, for which demand is much greater than supply. Production of superfine wire (0.0015-in. and smaller) increased about 11% the first half of 1944 over the same period in 1943, although only 58% of the number of dies was required to draw the greater quantity of wire indicating improvement in die manufacture and better utilization of dies.

Several wire makers are making tests to ascertain whether Brazilian diamonds produce superior, though more expensive, dies than those from South African diamonds.



A Coast to Coast Metal Stamping Service

Precision stampings, using unusual alloys, of intricate contour and produced to closest tolerances in Presteel's modern plant, have helped many manufacturers to lower the costs of parts or products formerly made of forgings or castings.

Because most of our work is beyond what other shops can do, customers for Presteel stampings are located in every section of the country. Our nearest representative will be glad to discuss drawing or forming problems with your engineers and the extensive experience of the Presteel engineering staff is always at your disposal.

1. N. B. Dunbar, 100 Barber Avenue
   Worcester 6, Massachusetts
2. George E. Quigley, Inc., General Motors Building
   Detroit 2, Michigan
3. G. Henry Jernberg, 17 East 42nd Street
   New York 17, New York
4. Albert S. Johnson, 211 South Chester Road
   Swarthmore, Pennsylvania
5. Albert H. Dervin, 217 18th Street N.W.
   Canton 3, Ohio
6. Bertram Bredy Company, 549 West Randolph Street
   Chicago 6, Illinois
7. Walter J. Hansen, 619 Stinard Avenue
   Syracuse 4, New York
8. R. A. Brand, 5315 North 16th Street
   Arlington, Virginia
9. Lawrence H. Burns, 837 Potomac Avenue
   Buffalo 9, New York
10. G. R. Marshall & Company, Confederation Life Building
    12 Richmond Street, East, Toronto 1, Ontario, Canada
11. A. M. Ferguson, 1235 Gaylord Street
    Denver 6, Colorado
12. J. Edwin Aspinall, 314 East New York Street
    Indianapolis 4, Indiana
13. E. C. Hanpeter, 1502 St. Louis Avenue
    St. Louis 6, Missouri
14. Walter P. Alexander, 420 Market Street
    San Francisco 11, California

WORCESTER PRESSED STEEL CO.

911 Barber Avenue, Worcester 6, Mass.

ALLOY STEELS AND OTHER METALS COLD FASHIONED SINCE 1883

● Said to completely eliminate all danger of over or under-tightening, thread stripping and material damaging a new torque screw and bolt driver is announced by *Richmont, Inc.*, 215 W. Seventh St., Los Angeles. It is 7¾ in. long, with a 1.30-in. diam. handle. Called the "Roto-Torq," is may be adjusted to any torque desired between 1 in.-lb. and 25 in.-lb. It operates on a new spring principle.

Annealing Brass Cartridges in Salt

A full anneal of brass cartridge cases on a continuous production heat treating basis is being done in a Detroit plant with the

longest continuous conveyor-type salt bath furnaces in the U. S., with unequalled absence of oxidation. The anneal on the brass is both full and bright. They were made by the *Upton Electric Salt Bath Furnace Div.*, 7450 Melville Ave., Detroit, Mich.

The cases come out without the slightest trace of oxidation, neither pickling nor other cleaning being required. Two furnaces are used, each capable of annealing 6,000 lb. of brass per hr. The first gives a full anneal at 980 F. before nosing. The second full anneals at the same temperature after nosing. Each furnace replaces ten non-continuous furnaces previously used, and paid for themselves in the first three weeks of operation.

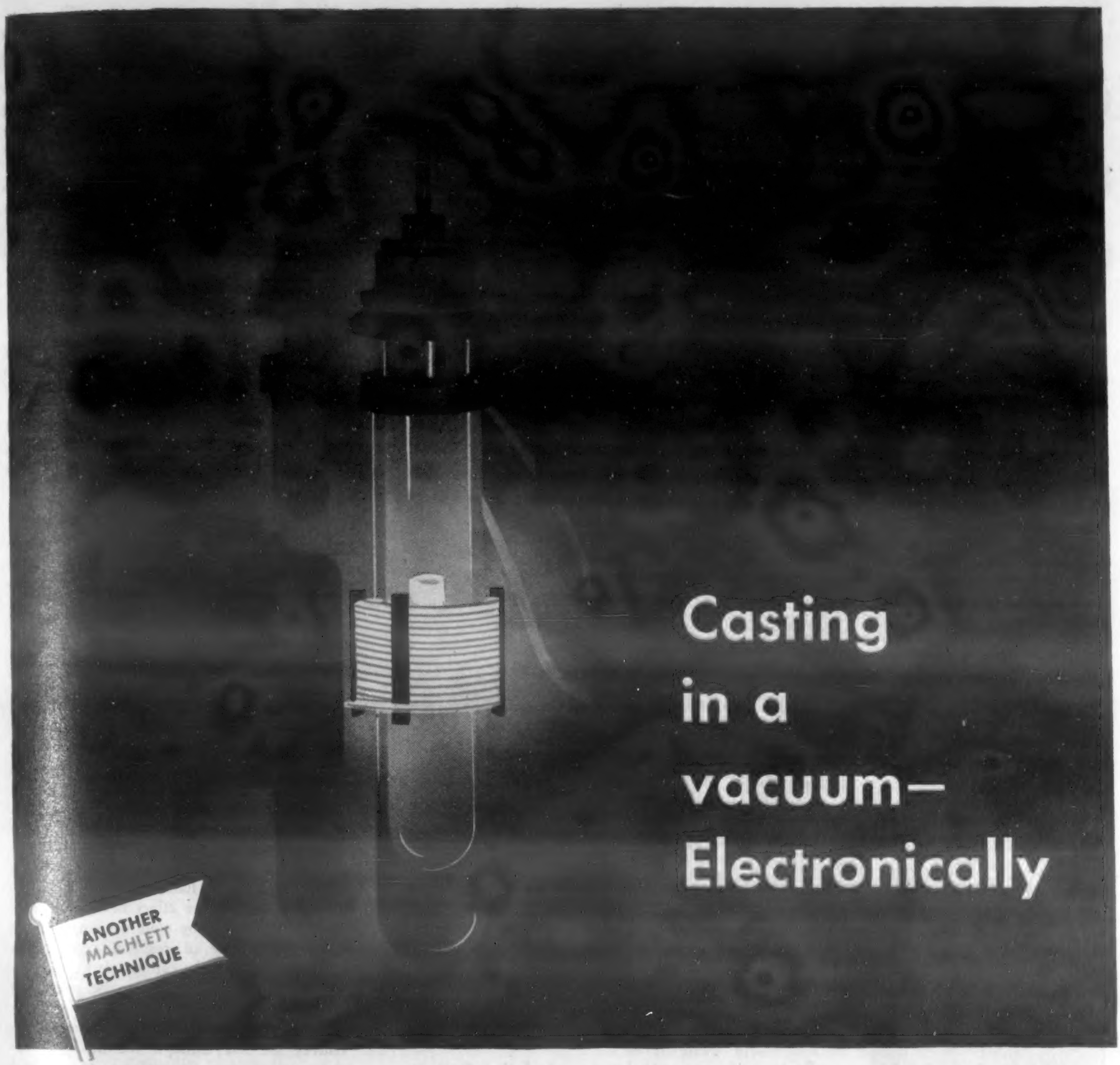
Cases are lowered into the molten salt at one furnace pot end and moved through at 60 ft. per min. A "turn-around" area at the other end permits the conveyor to bring the cases back through the pot to complete the full anneal. Drag-out of salt is at a minimum.

Three shell cases are suspended from each hanger of the conveyor, thus taking full advantage of the entire width of the pot. All is automatic except an occasional shovel full of replenishing salt.

Temperature of the bath is kept within ±5 F. by automatic electric temperature control. An emergency horn blows if the temperature goes wrong (but it has never been sounded). The first furnace has been in continuous operation for 18 mo. and has been shut down only twice for cleaning.

Electrodes enter the sides of the furnace instead of being thrust in from above the surface of the salt, thus insuring uniform

(Continued on page 1444)



One of the many vital processes that give Machlett vacuum tubes their remarkable quality is a novel method of casting electrodes in a vacuum. Anodes for X-ray tubes, and complex parts of high-frequency oscillators are made by this unusual technique. Purified copper rod is placed over a mould in a graphite crucible, and the whole enclosed within a double-walled water-cooled quartz-silicon tube, which is encircled by a high-frequency coil. A vacuum of about 10^{-5} mm. of mercury is maintained.

When the current is turned on, the metal melts and flows into the mould. Cooling is precisely controlled by adjusting the position of the heating coil, so that crystals form longitudinally, for maximum heat transfer under operating conditions.

This method accomplishes a number of things, quickly and simply. No gases can be occluded in the metal to shorten tube life by reducing the vacuum. Oxides cannot form. There are no "pipes" in a casting thus poured. Dimensions can be held to about 1/10,000th of an inch—and accurate dimensions are as important as metal purity in protecting tube performance, both assuring the maximum designed performance and long life. Techniques such as this make possible the production of the tube shown above . . . Machlett Laboratories, Inc., Springdale, Connecticut.

ML-846—An U. H. F. transmitting tube for television and F. M. and short wave broadcasting.

MACHLETT

X-RAY TUBES SINCE 1898

TODAY THEIR LARGEST MAKER

temperature. Transfer of current through the salt generates the heat at the bottom of the pot rather than above that point.

The flow of heated salt circulates upwards, thereby heating the entire contents of the bath evenly. Such electrodes, not exposed to combined action of salt and oxygen, last almost indefinitely.

Inexpensive commercial nitrate salts are used, and only 20% of the volume of salt previously used is now required.

● Release of an electronic circular chart electric controller for manufacture of either war or civilian goods is announced by the *Brown Instrument Co.*, Philadelphia. This is one of the first of its several electronic instruments to be released in quantities and with no rationing system planned. This recorder is being used in the metallurgical and chemical industries. The release stipulations specify eight weeks for delivery of two models. Each model will have several new features, including a control point index, which is in red and of the same general shape as the black temperature pointer.

Shop Peening Machines

A series of machines for throwing shot with centrifugal force upon metal surfaces to improve their quality is announced by *American Foundry Equipment Co.*, 555 S. Byrkit St., Mishawaka, Ind. In the "Wheelapeening" machines, a rain of metallic shot is directed against gears, springs, axles, etc. at high velocity. Each shot makes a tiny dent, the cumulative effect being to stretch the surface layers by cold working, to put them in a state of residual compression where fatigue cracks cannot start.

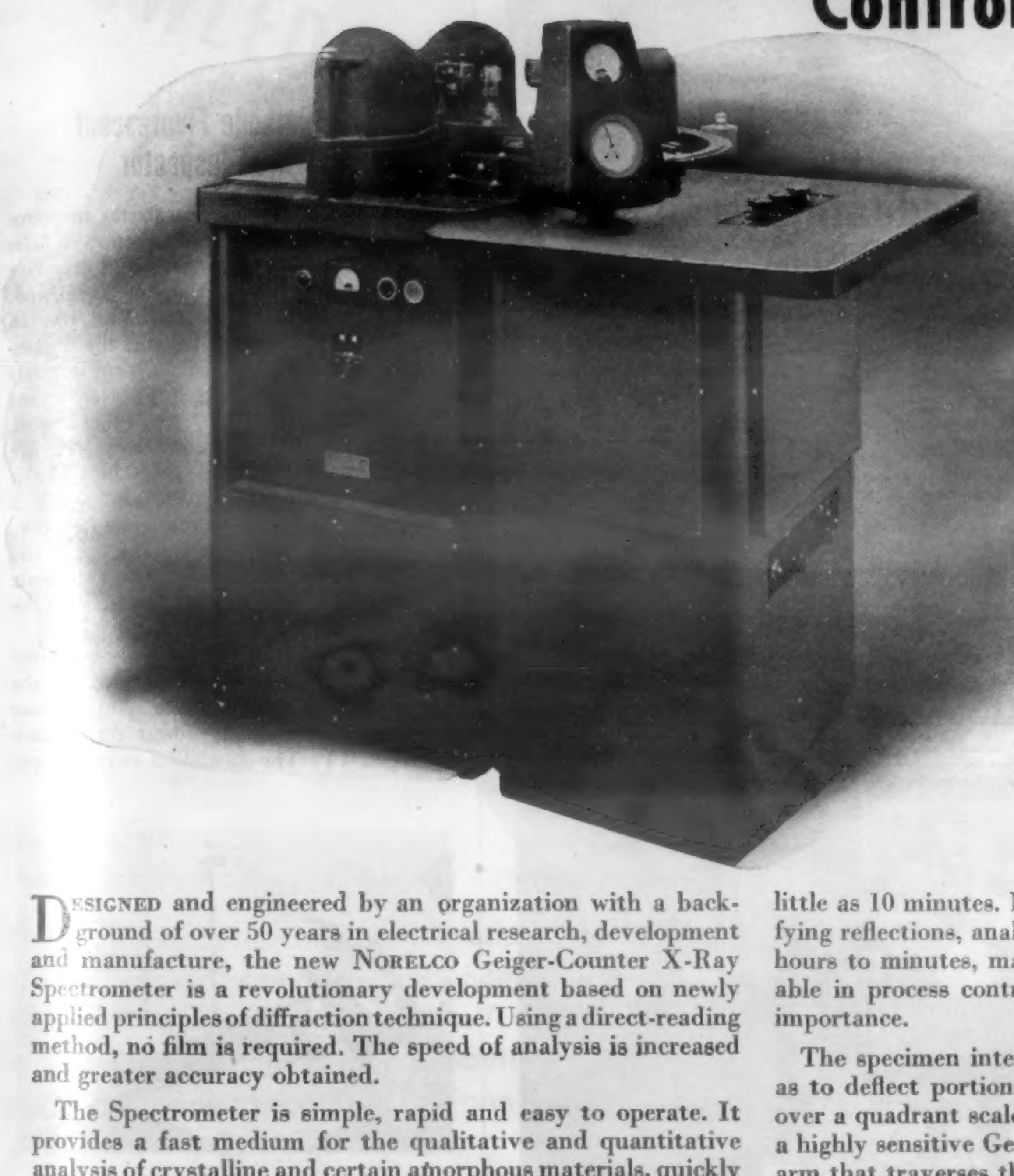
Assume that the work to be peened is a torsion bar. This is placed on skewed-dished rollers, outside the machine, which convey the bar through the machine, rotating it so that all surfaces are exposed when inside the machine. Within the machine a "Wheelabrator" hurls a rain of shot at high velocity onto the surfaces of the bar. This is a mechanical unit that uses controlled centrifugal force instead of compressed air for throwing shot, hence is cheaper.

Shot is fed to the center of the bladed wheel from an overhead storage hopper, whence it is thrown upon the work. An impeller rotates with the wheel proper and carries the shot to an opening in the stationary control cage, where it discharges to the bladed section of the wheel. Then the shot is picked up by the inner ends of the throwing blade, being gradually accelerated to the wheel's periphery. The final throwing velocity is the result of radial and tangential forces.

Provision is made for the continuous reuse of shot, for removal of broken shot and dust, and the addition of new shot. The equipment promotes much higher speeds, reduces power requirements by 80%, and saves costs.

Announcing—the NEW Norelco

Geiger-Counter X-Ray Spectrometer for Process Control and Research



Simplicity of operation and speed of obtaining direct readings are outstanding features of this new Spectrometer.

DESIGNED and engineered by an organization with a background of over 50 years in electrical research, development and manufacture, the new NORELCO Geiger-Counter X-Ray Spectrometer is a revolutionary development based on newly applied principles of diffraction technique. Using a direct-reading method, no film is required. The speed of analysis is increased and greater accuracy obtained.

The Spectrometer is simple, rapid and easy to operate. It provides a fast medium for the qualitative and quantitative analysis of crystalline and certain amorphous materials, quickly identifying chemical substances present and their state of chemical combination.

Components of mixtures in the order of one per cent and often less can be measured. Under optimum conditions of resolution, diffraction angles are obtained with an accuracy of ±0.03 degree.

Identification of certain substances has been effected in as little as 10 minutes. By concentrating on characteristic identifying reflections, analysis time can frequently be reduced from hours to minutes, making the Spectrometer particularly valuable in process control where the time element is of highest importance.

The specimen intercepts an X-ray beam in such a manner as to deflect portions of the beam at various discrete angles over a quadrant scale. The reflections are located by means of a highly sensitive Geiger-Counter tube mounted on a movable arm that traverses the scale. Radiation intensity is integrated and totalized by an electro-mechanical counter, while average intensity is indicated by a microammeter, both connected to the Geiger-Counter through electronic circuits.

Judging from results already obtained, the NORELCO Geiger-Counter X-Ray Spectrometer will have a wide field of application as a research instrument and as an industrial tool. Write today for descriptive literature, prices and delivery date.

OTHER NORELCO PRODUCTS: Quartz Oscillator Plates; Amplifier, Transmitting, Rectifier and Cathode Ray Tubes; Searchray (Industrial X-ray) Equipment; Medical X-ray Equipment, Tubes and Accessories; Electronic Measuring Instruments; High Frequency Heating Equipment; Communications Equipment; Tungsten and Molybdenum products; Fine Wire; Diamond Dies. It will pay you to visit our Industrial Electronics Showroom when in New York.

Norelco Electronic Products by
Reg. U. S. Pat. Off.

NORTH AMERICAN PHILIPS COMPANY, INC.

Dept. M-11, 100 East 42nd Street, New York 17, N. Y.

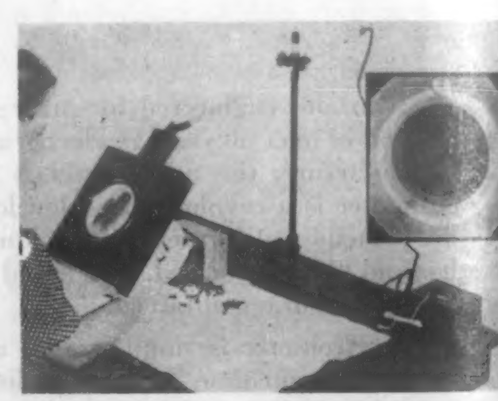
Factories in Dobbs Ferry, N. Y.; Mount Vernon, N. Y. (Metalix Div.); Lewiston, Me. (Elmet Div.)
Represented in Canada by Electrical Trading, Ltd., Sun Life Bldg., Montreal, Centre 2; in England by Philips Lamps, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

● A new, small, gas-fired rivet heating forge, handy in confined spaces, is being publicized by *James H. Knapp Co.*, 4920 Loma Vista Ave., Los Angeles 11. It operates on compressed air and natural gas, and is complete with burner and control valves. Heating space is 8 in. diam. and 7 in. deep. The bottom lining of chrome refractory will not slag with rivets. It weighs 85 lb., and has lifting hooks for easy moving. It can be furnished for operation on light oils.

Cold Cathode Fluorescent Lighted Inspector

A new cold cathode, no-starter inspector has been introduced by the *Larrimore Sales Co.*, P. O. Box 1234, St. Louis 1. Five advantages of this equipment are listed: The "no-starter" works on-and-off like an ordinary old style incandescent; the fluorescent tubing is in circular form entirely around the 5-in. magnifying lens (but shields from the lens), resulting in soft, clear daylight with no shadows; the life of the fluorescent tubes is 10,000 hr.; it operates on 115-v., 60-cycle a.c., which is converted by a small transformer, 2000-v., 18 m.a. secondary, installed for safety and efficiency; the transformer is in a separate housing, which can be fastened up near the plug-in.

The lighting principle is fully approved in other fields and is here offered for the first time for inspection. The sponsors most candidly and unusually admit three disadvantages: (1) The on-and-off switch cannot



be placed in the head, but must be in the transformer box near the plug-in; however, a pull cord is provided; (2) the replacement cost of the tubes and time needed to change is greater than with ordinary fluorescent, but the tube's long life and shadow-free light compensates; and (3) the units are not available in the double lens types, nor for installation over grinding wheels or such locations.

● A 70-gal. dipping and melting tank for large volume production, called the "Waxmaster Major," is announced by the *Aeroil Burner Co., Inc.*, 5701 Park Ave., West New York, N. J. Over 550 lb. of wax can be melted and heated in 75 min. Electrically heated, the thermostat regulates temperatures automatically from 100 to 550 F.

● A sample of the new Coleman buffer tablet (5.00 pH) will be supplied to any chemist or metallurgist who requests it on his company letterhead, states *Burrell Technical Supply Co.*, 1936 Fifth Ave., Pittsburgh 19. The sample has a pH of exactly 5.00 pH when diluted in 100 ml. of warm distilled water. The tablet provides a simple and accurate method of preparing buffer solutions for the laboratory. The tablets are available in steps of 0.20 pH over the range of 2.00 to 12.00 pH. Twelve tablets of the same pH are hermetically sealed in a glass vial. Solutions are accurate within 0.20 pH.

Powdered Alloy for Tool Tipping

The use of powdered alloy, mixed with flux, between tip and shank is often preferable to foil where carbide and high-speed steel tips are applied, states *Eutectic Welding Alloys Co.*, 40 Worth St., New York 13. The foil may become tarnished or oxided, requiring a temperature far above its melting point to flow freely. It is inconvenient to cut the foil into small pieces for exact preplacing.

Eutectic Welding Alloys Co. mentions one outstanding copper alloy and two silver-copper alloys available in a fine powder for tipping. These alloys, are EutecRod 1800, 1601 and 16.

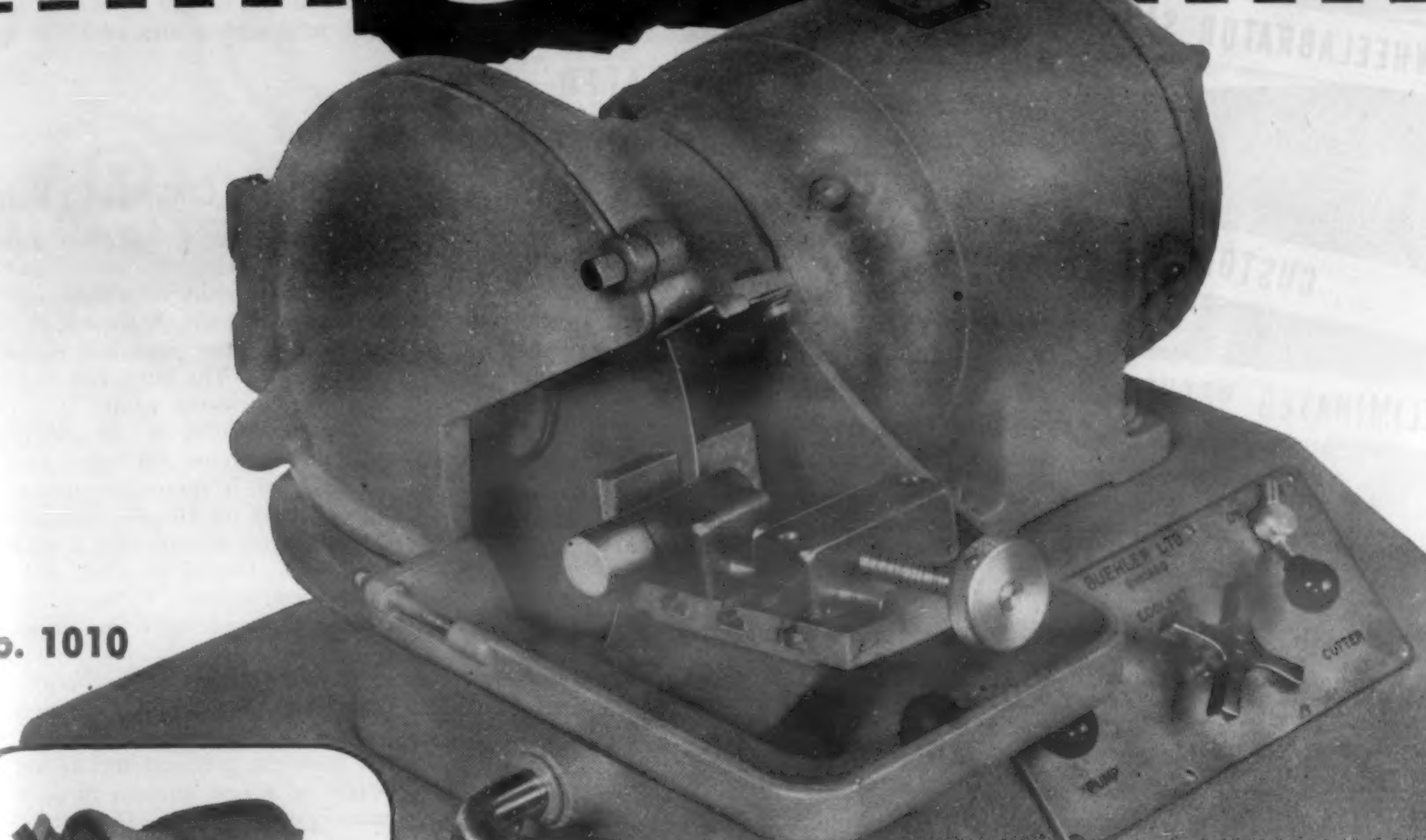
After degreasing and grinding, the powdered alloy is spread on the surfaces to be joined and the tungsten carbide tip is placed on top. The assembly is heated until the alloy melts.

The metal flows freely at a very slight increase in temperature above the melting point, since the weld metal is pulverized. Oxidation of the tungsten carbide is prevented, as each particle of molten alloy immediately "tins" and adheres to the surfaces being joined.

EutecRod 1800, lowest melting, is for high-speed steel, operating at 940 to 1140 F.; the No. 1601, high tensile, is for tungsten carbide, at 1020 to 1250 F.; the No. 16, heat resistant and high tensile, is for tungsten carbide at 1300-1750°F., furnace temperature.

● Studies made by the *Bureau of Mines* of the clay content of 22 natural molding sands indicate that many domestic clays can be used successfully by foundry operators to produce synthetic sands for castings. It is found that the bonding material found in natural molding sands is similar in composition to many clays, such as refractory shales, low grade fire clays or high grade fire clays. A copy of the publication, Report of Investigations 3774, "The Composition and Properties of Molding Sands—Part I. The Nature of the A. F. A. Clay Fraction Removed from Natural Molding Sands," may be obtained free from the *Bureau of Mines*, Department of the Interior, Washington 25, D. C.

Buehler



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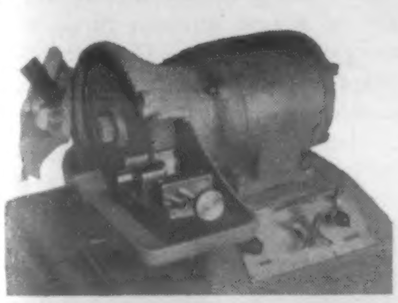
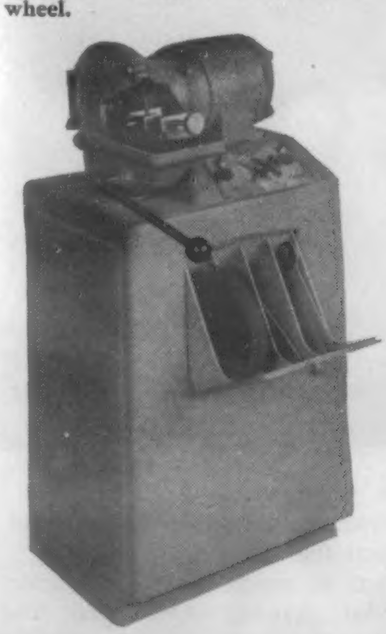


Splash guard opened showing jet pipe for coolant; a companion jet is on the opposite side of the wheel.



Complete view of cabinet showing storage bin for extra wheels and tools.

NEW 1 H. P. Cut-Off Machine

A laboratory size cutter with ample power for fast cutting of samples up to 1" in diameter.

This cut-off machine is built with the usual Buehler emphasis on precision in both the construction of the machine itself and the work it performs. The controls are arranged for the utmost convenience of the operator—a feature that contributes to speed and accuracy in cutting samples.

The cutting wheel mounted directly on the ball bearing motor shaft is free from side play or vibration and is cooled by a stream of coolant directed on both sides of the wheel under the guard.

The cutting is done on the front of the wheel by using the long lever handle to raise the clamp base holding the sample to contact the wheel. This mechanism is balanced so that pressure against the cutting wheel is under perfect control at all times by the operator. A metal splash guard, removed in the illustration, furnishes protection from spray.

Overall dimensions are 24" x 28" x 50". Shipping weight, 575 lbs.

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . .
CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS
EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS
POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

Buehler Ltd.

A PARTNERSHIP

METALLURGICAL APPARATUS

165 WEST WACKER DRIVE, CHICAGO 1, ILLINOIS

● A new test paper for detecting porosity in plated coatings is heralded by the *Hanson-Van Winkle-Munning Co.,* Matawan, N. J., called "Fotopor." It commonly detects porosity of nickel on iron and steel, but can also test chromium, brass and tin over iron and steel; also, these metals over copper and brass. Blue spots appear on the paper when iron or steel is exposed; brown spots, for copper and brass. It comes in rods of 150 lineal feet, 2 in. wide, with total surface area of 3600 sq. in.

Printing Drawings on Metal

Materials for a simplified method of printing working drawings directly on metal have recently been announced by the *Eastman Kodak Co.,* Rochester, N. Y. These are Kodak layout paint and Kodak layout paint primer. The latter acts as a subbing base for the layout paint. It is of widespread applicability for the production of products involving flat metal parts.

The paint is sprayed in ordinary room light directly on virtually any primed and cleaned metal surface with a conventional spray gun. Drying is rapid, and the prepared metal is ready for immediate use or it can be stored for a reasonable time in a dark place.

The drawing, which has been previously prepared with black ink on a transparent or translucent material, is next laid in contact with the prepared surface and an exposure of a few minutes made to arc or mercury vapor lights. The drawing is removed and the metal flooded with warm, weak ammonia water. A vigorous spray of tap water follows, which washes away the entire exposed coating, leaving only white

lines where black lines appeared in the drawing. Another thin spray coat of primer protects the finished product.

Parts so marked are as accurate as the original drawing. On metal, the paint withstands bending, shearing and punching without showing any tendency to loosen, and will actually resist a cutting torch to the point where the molten metal carries it away, provided there is no scale.

(*Continued on page 1452*)

Research Leadership

Back of Every Ingot

The spectrographic department at Apex carefully measures the ranges of alloying elements of every heat of metal by the use of the densitometer. Such close laboratory control guides the removal of harmful elements and permits meeting the most exacting alloy specifications. This pre-testing of alloys is an important part of Apex Leadership Back of Every Ingot.

APEX SMELTING

Company · Chicago 12, Illinois

The method has an advantage over scribing because operators' instructions, which are inked on the drawing, are transferred to the part to be fabricated. Reductions in scrap loss are forecast in that a layout can be prepared so as to include parts for several products. By so doing, maximum use of metal can be achieved.

There are no critical steps involved, and an inexperienced operator can do it rapidly. It is suitable for metal having uneven or oxidized surfaces.

● More than 100 basic materials, including metals, can be marked with the Floquil Fountain Marker, developed by *Floquil Products, Inc.*, 1974 Broadway, New York 23. It marks any surface, wet or dry, hard or soft. The marker consists of three non-moving parts. There are seven standard transparent colors. It drys instantly, and is weather and abrasion proof.

Hydraulic Powdered Metal Press

A new hydraulic press for briquetting parts from powdered metal, designed to simplify powdered metal molding and give a high degree of accuracy and consistently uniform structure density in finished products, is announced by the *Watson-Stillman Co.*, Roselle, N. J.

The press has a 400-ton capacity vertical ram and a 300-ton horizontal ram. It is double acting, with convenient controls and adjustments. Exact duplication on production runs is assured by smooth, pulsationless pressure application, accurate stepless pressure adjustment and automatic cycle controls. Micrometer adjustment of pressure is provided on the working stroke. The mold size is 6 in. wide, 7 in. deep and 30 in. long.

Pressure is provided by a radial piston-pump, driven by a 30-h.p. motor. The machine has a pushbutton, solenoid-operated pilot valve for down and forward movements of the press ram. Operating speeds of vertical ram are 238 in. per min., advance and return; 17.5 in. per min., pressing. Horizontal ram advance and return speeds are both 21.6 in. per min. The press is 11 ft. 6½ in. in height overall, weighing 28,000 lb.

● Extra performance dies for drawing of fine steel wire of 0.015-in. diam. and under, R-1 dies, and made from Grade 999 cemented carbide, are now carried in stock at *Carboloy Co., Inc.*, Detroit 32. This is the hardest metal produced by Carboloy. It produces wire of great uniformity, high surface finish and over a long run. They do certain jobs that only diamond dies could previously perform.

2,000,000-Volt X-Ray Tube

Machlett Laboratories, Inc., Springdale, Conn., largest manufacturers of X-ray tubes in the world, have produced an X-ray tube that operates at 2,000,000 volts. The new high-voltage tube is completely sealed off, so that pumping is not needed to maintain

the vacuum. It is d.c.-operated, and was developed for the High Voltage Laboratory at Massachusetts Institute of Technology.

The tube uses a gold transmission target ½-in. thick, the beam passing through the target. About 180 accelerating electrodes are placed along the length of the tube. Some idea of what the increase in voltage from the former high of 1,000,000 volts will mean to radiographic study of thick steel objects is given by imagining such a thickness of steel that the 2,000,000-volt tube would require an exposure of one hr. At 1,000,000 volts, the theoretical exposure time would be one week, while at 500,000 volts about 500 years would be required.

Increasing the voltage of the X-ray tube from 1,000,000 to 2,000,000 volts, while advantageous, was enormously difficult. It is probable that the limit in tube voltage possible to achieve is somewhere in the neighborhood of 2,000,000 to 4,000,000 volts, as the higher velocity makes necessary a longer tube to focus over a sufficient area. The 2,000,000-volt tube is about nine ft. long.

● A revolutionary substitute for structural steel columns has been developed in Northwestern University's Technological Institute, according to *Pathfinder Magazine,* Washington 5. It is claimed stronger and cheaper than all-steel, light as aluminum, and composed 80% of concrete. Inside a spiral steel wire a metal lining is placed. Into this tube concrete is compressed with a steel plunger. Only one gallon of water is used to a sack of cement. Tests showed the column would support loads much heavier than a steel column the same size. Cost of production is 67% less than all steel.

Rust Preventive Oils

A new line of rust preventive oils and fingerprint removers, designed chiefly for packaging, is announced by the *Shell Oil Co., Inc.,* 50 W. 50th St., New York 20. Known as the Ensis line, they are made up in four different types of products, available in 14 grades, graduating from thin, transparent, oily films that need not be removed before use, to heavy, abrasion-resistant coatings able to withstand moisture over extended periods of time.

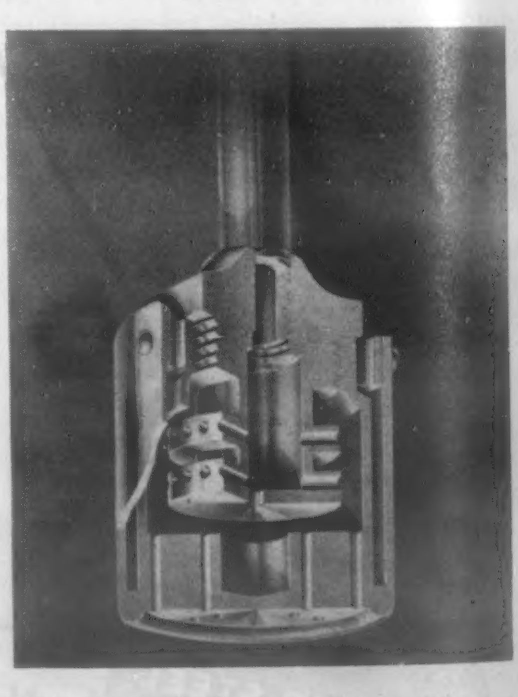
One of the products will dissolve fingerprints, displace water, and afford long-range protection against high humidity during storage. A heavier, extremely powerful preservative is for packaged precision parts or for unpacked equipment.

All are much easier to apply and remove than old style semi-solid compounds, used for years on rifles and arm parts. The oils protect in any climate and in all kinds of conditions encountered in overseas shipments.

Multi-Flame Heating Nozzles

A new heating nozzle, designed particularly for oxygen and liquefied petroleum gases or natural gas, is offered by *Victor Equipment Co.,* 844 Folsom St., San Francisco 7. It fits all standard victor welding torch butts, but can also be sold complete.

An outer air mantle protects the nozzle head against deflected heat, designed so that the cool and pre-mixed gases carry away a substantial amount of accumulated heat, and in doing so become efficiently preheated for proper combustion.



Similar multi-flame heating nozzles are also available in numerous sizes for use with oxyacetylene. The larger are good for flame priming and descaling in inaccessible areas. All can be employed for silver brazing operations, preheating, and bending. Multi-flame nozzles are a useful adjunct to all good welding torches.

MISCO HIGH TEMPERATURE ALLOY
SHEET CARBURIZING BOXES

Fabricated in a wide range of sizes from MISCO 35-15, MISCO 25-20 and Inconel depending on service conditions

Misco Sheet Box made in 3/16" Misco Metal, 35% Ni. - 15% Cr., sheet. 16" I. D. x 20" deep.

The construction of Misco High Temperature Alloy Sheet Carburizing Boxes is planned for most efficient service. Misco Sheet Boxes are at least 50% lighter than cast boxes of equal capacity. Thermal stresses are reduced and pound for pound they last longer. Misco Sheet Boxes heat rapidly, save fuel, and reduce handling time. Based on our experience with thousands of carburizing boxes of all types, Misco Sheet Boxes afford maximum service per dollar of investment and provide the greatest output in a given period of time . . . We will be pleased to furnish you with complete details regarding the many advantages of Misco Sheet Carburizing Boxes.

OTHER MISCO HEAT-TREATING EQUIPMENT

Furnace Parts • Roller Rails • Conveyors • Roller Hearths • Conveyor Rolls • Trays • Retorts • Thermocouple Protection Tubes • Chain • Walking Beam Conveyors • Carburizing and Annealing Boxes • Dipping Baskets • Cyanide and Lead Pots • Centrifugal Castings and Miscellaneous Castings for use at high temperature or under corrosive conditions.

★ Invest all you can in WAR BONDS ★

MISCO
Heat and Corrosion Resistant Alloys

Michigan Steel Casting Company

One of the World's Pioneer Producers of Heat and Corrosion Resistant Alloy Castings

1999 GUOIN STREET, DETROIT 7, MICHIGAN

● The Rivnut, the blind fastener that serves as a nut-plate, rivet or both, is now being made of brass as well as aluminum, states *B. F. Goodrich Co.*, Akron, Ohio. Tensile and shear strength of the brass are 50% greater than the aluminum fasteners. First applied to the aircraft industry, the Rivnut has been adapted to other industries.

Tachometers

A new form of tachometer is now available for engineers, setup and maintenance men, and time-study groups. It weighs but 5½ oz. and is 2¼-in. in diam. The recording in r.p.m. is easily read, without the use of any timing or counting device.

The readings are constant, and record

fluctuations that are impossible with tachometers now on the market. The scale is made up of black figures against an orange background.

The range of this instrument runs from 500 to 3600 r.p.m., and checks of stock models show a variation of less than 3% from absolute accuracy over the whole range. Standard units have been subjected to 50,000 test readings without recording any variation in the accuracy of the reading from start to finish.

A pointed contact spindle is for use with shafts that are centered, and an elastic tip is furnished that will slip over the pointed spindle for use on shaft ends that are not centered. It is dust and moisture proof, and has a baked enamel protective coating on all surfaces except the scale, which is enclosed in a plastic tube. *The Standard Machinery Co.*, Providence, R. I., is the designer and manufacturer.

● "Letter-Outline" hand stamps that can impart various information in one design are announced by *New Method Steel Stamps, Inc.*, 147 Jos. Campau, Detroit 7. It is handy where several sub-contractors supply the same part, identifying the contractor and even the individual operator or inspector involved.

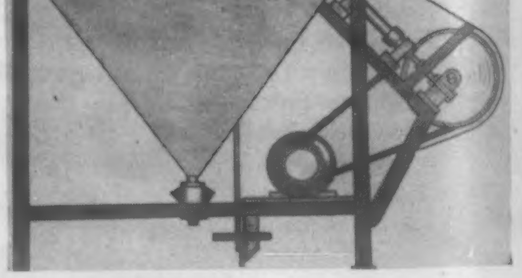

AMCO EQUIPMENT
for steel mills ...

● Stating that there is a definite trend towards using snap gages by which the inspector can see rather than feel the variations in dimensions, *Federal Products Corp.*, 1144 Eddy St., Providence 1, R. I., announces Model 1330 P-100 dial indicator type of snap gage. The weight of the gage in the operator's hand rests upon a fixed contact and not upon a sensitive contact. The lower anvil is retractable and can be applied to the work without marking fine finishes. It has a low friction movement that transfers the movement of the contact point to the indicator without error.

Sandblast Machine

A new type of sandblast that is a combination of the sandblast cabinet with stationary nozzle and rotating basket or tumbling barrel type is announced by *Leiman Bros., Inc.*, 160 Christie St., Newark 5, N. J. The sandblasting cleans the surface of metals of rust, scale, etc. before electro-plating, enameling, painting, etc. It also produces satin finish effects, and stenciling of designs or lettering are quickly, accurately and very distinctly produced. Plate and enamel will be firmer and more lasting on a sandblasted base.

The rotating basket is fitted inside the cabinet in such a way as to handle many small items, such as nuts, screws and small gadgets. The rotating basket is filled, and the machine sandblasts automatically as parts are tumbled. The basket may be removed where larger pieces are to be



treated. The basket is motor driven. The sand is fed through the nozzle over and over from the reservoir at the bottom of the cabinet.

Castings that have been sandblasted clean of scale and burnt casting sand can be more speedily machined. Lathe tools will hold their cutting edges longer when castings are clean.

(More News on page 1464)

The villain of this film threatens *your* plant, too!

FIRE, the saboteur, can destroy your plant—even though you've installed the most modern fire-fighting equipment! If your men don't know how to operate it, or if they use the "right" equipment against the wrong fire, disaster can easily result.

Believing that visual instruction is easiest understood, longest remembered, Walter Kidde & Company have produced a color film with sound. It shows exactly what to do when fire strikes. It pictures the different classes of fire, shows how to fight each of them. It's fast-moving, grips the attention of its audience during the twenty minutes of its run.

We'd be glad to show this film to key men at *your* organization. There is no obligation whatever for this service. Just drop a line today to the address below and we'll arrange a showing at your convenience.

Kidde

WALTER KIDDE & COMPANY, INC., 140 CEDAR STREET, NEW YORK 6, N. Y.

Spot and Seam Welder

An important new development in resistance welding was announced at the Metal Show in Cleveland, Oct. 16 to 20, by *Progressive Welder Co.,* 3050 E. Outer Drive, Detroit 12. The machine is a "Universal" resistance welder—capable of either spot welding or seam welding—and operated by storage batteries rather than through transformers from power lines, etc.

It will permit performing of welding operations heretofore considered impractical. These include the spot welding of structural aluminum sections of considerable thickness (up to 3/16 in. or more) and the seam welding of aluminum of the same thickness at high speeds.

One of the contributing factors is an entirely new development in seam welder wheel design originated by *Frostrode Products,* 19929 Exeter, Detroit 3. This wheel is internally refrigerated, requiring no external water supply, and has a replaceable rim, reducing wheel renewal cost when the wheel is worn. The machine works well on steels, etc.

● A lubricant that reduces wear and reduces inspection time of gages, called CMD Center Point, is announced by *Chicago Mfg. & Distributing Co.,* 1928 W. 46th St., Chicago. It prevents sticking of overworked gages, whether plug, ring, snap or thread gages. It prevents corrosion, and a wiping film of oil lasts from one to two hours.

Corrosion Resistant for Zinc-Alloy Die Castings

A quick chemical process for brightening and improving the corrosion resistance of zinc alloy die castings, called Zinctone, is announced by *Turco Products, Inc.,* 6135 S. Central Ave., Los Angeles 1. It seals the outer "skin" of the casting, protecting from mechanical and corrosive attack. It gives a smooth bright surface comparable to mechanical polishing or buffing, and brings out a lustrous silvery bloom.

Zinctone can treat new castings or reclaim used zinc alloy die casts. It removes stains and corrosion, seals, passivates and brightens. Carburetors and fuel pumps are typical reclaimable items.

Adaptable to small shop and mass production set-ups, it uses simple immersion equipment. It may be handled by unskilled personnel.

● A new radius and angle forming instrument, known as Radiform, has been developed by the *W. F. Meyers Co., Inc.,* Bedford, Ind. This device will generate radii and angles tangent to radii on end mills, die sinking tools, drills, reamers, etc., both straight and spiral fluted, directly against a grinding wheel, without preforming the wheel.

Mr. Cone Goes to Washington

Edwin F. Cone, consulting editor, METALS AND ALLOYS, and well known in metals engineering and technical journalism fields, has been called to Washington on a special editorial assignment of the War Metallurgy Committee, involving preparation of committee reports. His services have been loaned by METALS AND ALLOYS on a full-time but temporary basis.

News of Engineers

Victor F. J. Tlack, pioneer developer of cobalt, chromium steels, has become consultant and special sales representative of Latrobe Electric Steel Co., Latrobe, Pa. Until recently, Mr. Tlack was president of Darwin & Milner, Inc., tool steel jobbers, Cleveland, with whom he was associated for 30 years. He will be located at Latrobe's Cleveland office.

Elbert A. Hoffman and *John M. Birdsong* have joined the metallurgical engineering staff of LaSalle Steel Co., Chicago. Mr. Hoffman took advanced courses in metallurgy, metallography, heat treating and welding metallurgy at Illinois Institute of Technology and was later with American Steel & Wire Co. Mr. Birdsong graduated from Illinois Institute, and has had extensive steel, heat treating and machining experience, largely with General Electric.

Olin H. Philips is now in charge of extensive laboratory metallurgical research of the American Car & Foundry Co., succeeding *John W. Steinmeyer*, who was transferred to the New York research department. He has been in the metallurgical department of Jones & Laughlin Steel Co. for ten years.

D. E. Jack has been elected vice president in charge of engineering and sales of the Duriron Co., Inc., Dayton, Ohio. *R. C. Schenck* has been made vice president in charge of production. *J. M. Williamson*, for 16 years with Allis-Chalmers Mfg. Co., is now chief engineer. *O. J. Jacobsen*, formerly chief engineer, is in charge of engineering research and development.

A. J. M. Baker has been elected director and vice president, E. W. Bliss Co., Brooklyn. He was formerly general manager, Crocker-Wheeler Electric Mfg. Co., Ampere, N. J. div., Joshua Hendy Iron Works, Sunnyvale, Calif. Previously, he was deputy director general, British Purchasing Commission.

Glenn W. Shetler is now vice president in charge of operations, Barium Steel Corp.,

Canton, Ohio, having been general manager. He was previously with Crucible Steel Corp.'s Halcomb Works, Syracuse.

W. R. Persons, Pittsburgh manager, Lincoln Electric Co., Cleveland, has been transferred to headquarters at Cleveland to plan for post-war.

E. H. Carmany has been appointed vice president in charge of eastern operations of Wyckoff Steel Co., with headquarters at the Empire Works, Newark, N. J.

Henry P. Kirchner, vice president, Carborundum Co., has been placed in charge of production. *Otis Hutchins* is named technical director in charge of research and process control and development.

Julius A. Clauss has been appointed vice president in charge of engineering, Great Lakes Steel Corp. *J. Emmett Fink* is now vice president in charge of operations.

O. C. Tabbert, formerly welding engineer, Milwaukee district, Harnischfeger Corp., has been made assistant manager, P & H Welding Equipment Division.

M. G. Werme, formerly superintendent, Clinton, Mass. plant, Wickwire Spencer Steel Co., is now chief development engineer. *Gordon Lloyd* has been made superintendent of the Clinton plant. *Victor Chartner* is appointed chief mechanical engineer.

J. M. Stapleton, former superintendent of blast furnaces, Geneva Steel Co., Geneva, Utah, has been promoted to assistant division superintendent of blast furnaces at South Works, Carnegie-Illinois Steel Corp. He is returning to the plant at which he worked for 22 years.

William S. Wilbraham, assistant to general manager, Lukenweld, Inc., has been appointed production manager. *George L. Snyder,* chief engineer of Lukenweld, is assistant to the general manager.

Three new works manager appointments have been made by Allis-Chalmers Mfg. Co.: *Hugo W. Liebert,* general works manager of the tractor plants; *Fred S. Mackey,* general works manager of the general machinery plants; and *Harry E. Ladwig,* works manager of the West Allis foundries and pattern shops.

J. P. Larkin is the new chief metallurgical and sales engineer of Firth-Sterling's steel division. For two years he was chief of the Tool Steel, Stainless and Lend Lease Alloy Steel sections, Alloy Steel Branch, WPB. *Andrew H. Godfrey* becomes assistant manager, Firthite Div., having been factory manager of Carboloy Co. *Anthony J. Allen* is a new assistant manager of the Firthalloy Div., having been for 15 years in the manufacturing end of the wire industry.

Wilbur C. Osha, general welding superintendent, Berwick, Pa. plant, American Car & Foundry Co., has been made general supervisor of welding for that company. He was first employed by the Pittsburgh Testing Laboratory.

Correction!

Due to an oversight, the color plate was omitted from the advertisement of Pittsburgh Lectromelt Furnace Corp. in our October issue. It is reprinted in its entirety on page 1369 of this edition.

Plants and Slants

In the interest of speed in war contract termination, *Wright Aeronautical Corp.*, Cincinnati, has installed a "visual control board" system, scheduling dates and steps in reconversion, eliminating its former ledger control. Thus, it has predetermined schedules for $128,000,000 and $50,000,000 terminations in 105 and 90 days, respectively. Known as "Produc-Trol," it is four times as fast as other methods. Each of seven major steps of the termination procedure is represented on the control boards by a different colored *vertical* line, the lines being superimposed on the scheduled completion date. *Horizontal* lines represent cancelled purchase orders. One can see at a glance the status of each order.

Another company to use an effective visual control is the *American Brake Shoe Co.* at its Meehanite foundry, known as the production schedule chart. Colored linen tapes of spring rewind type are soldered to clips screwed to the board. The man-days for each order are calculated as received and totalled according to molding method required. The tapes are then extended to the corresponding number of man-days and held in position by a small hook.

Ninety-four per cent of the employees of the *Inland Steel Co.*, now in armed services, expect to return to Inland after demobilization, according to a questionnaire sent to a majority of its 4000 in service. Those who have already returned number 225, eight of them wounded veterans, but adjusted to plant work again. One purpose of the questionnaires is to show the boys that Inland is still interested in them.

Effective plant morale propaganda are the moving picture films of actual battle scenes shown by the War Department. *Steel Products Engineering Co.*, Springfield, Ohio, wrote: "We showed 'War Department Report' to our employees during lunch, then found that our percentage of absenteeism for that week was the lowest in six months."

MetalFusion Corp. of America has become a subsidiary of *Cook Electric Co.*, Chicago, the latter having acquired a critically controlled atmosphere brazing plant, with furnaces for heat treating and annealing, atomic hydrogen, shielded arc, seam and spot welding, gas flux brazing, salt bath brazing and induction brazing.

Green Electric announces that *Crown Rheostat & Supply Co.*, 1910 Maypole Ave., Chicago 12, is now the exclusive distributor for all types of Green rectifiers in Illinois and Wisconsin. Crown Rheostat will also handle Green rectifiers in several adjacent states.

American Rolling Mill Co. has sold its No. 2 sheet mill to the *Reynolds Metals Co.* It will be rebuilt for rolling aluminum.

In announcing that two of its plants at Philadelphia have been awarded a fourth renewal of the Army-Navy "E", *Westinghouse* points out that less than two-tenths of 1% of the nation's war plants have achieved this honor out of the 100,000 plants eligible. Only 3,000 plants (3%) have won "E"'s, and only 176 a fourth renewal.

A 78-year old tradition in gun making was broken when Mrs. Olive Dahlberg, New Haven 37-year old mother of three children, became night superintendent of the *Winchester Repeating Arms Co.* She joined Winchester three years ago to operate a cartridge loading machine. Because of "ability to get along with people", she was transferred to the personnel department. Now she keeps materials flowing and shooting trouble, both mechanical and personnel.

The Fifth War Loan Drive went over with a bang at the *White Motor Co.*, Cleveland, because of a "popularity contest," in which 20 girls competed as representatives of their departments. A bond purchase meant a vote for "Miss Half-Trac," "Miss Scout Car," "Miss Transport," etc. Prizes of bonds went to the three most popular gals.

The *Wickwire Spencer Steel Co.* has purchased the *Sirian Wire & Contact Co.*, Newark, N. J., and has formed a new subsidiary, the *Wickwire Spencer Metallurgical Corp.*

Acme Pattern & Tool Co., Dayton Ohio, has changed its name to *Acme Aluminum Alloys, Inc.* This is the second time the company has outgrown its name, the original company of 1920 having been the Acme Pattern & Mfg. Co.

Construction of a new manufacturing plant on a 49-acre site in St. Paul will be started by the *American Can Co.* as soon after the war as labor and materials are available, costing $6,500,000 and employing 1,000.

The *Universal Wheel & Abrasive Corp.*, Chicago, is moving into a new and larger plant at 400 N. Ashland Ave., Chicago, this fall. Since its founding in 1935, the company has been forced to expand its space every six months.

Carnegie-Illinois Steel Corp. has leased to *Lukens Steel Co.* the right to manufacture "Cor-Ten" corrosion-resisting, high strength alloy steel.

Number 6 of a Series: "Looking at the 5 essential things you never see in electrodes!"

Formula for LEADERSHIP

plus Continuing Research

Continuing research has fed major improvements into "National" carbon and "Acheson" graphite electrodes for electric furnaces for upwards of 40 years. These improvements show up as steadily higher impact resistance, more uniform size, greater current capacity, slower consumption, and lower cost per ton of electric steel.

Without continuing research, our carbon and graphite electrodes could not have attained and held *leadership!*

Yet you cannot *see* "continuing research" in the products themselves. So we remind you again to investigate this quality, as well as the four other "essential things you never see in electrodes." The others: Raw materials selection, manufacturing experience, manufacturing control, and customer service. These things are present in every "National" and "Acheson" electrode. Your inquiries are invited.

NATIONAL CARBON ACHESON GRAPHITE

NATIONAL CARBON COMPANY, INC.
Unit of Union Carbide and Carbon Corporation
UCC
GENERAL OFFICES: 30 East 42nd Street, New York 17, N.Y.
DIVISION SALES OFFICES: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco
In Canada: Canadian National Carbon Company Limited, Welland, Ontario

The registered trade-marks "National" and "Acheson" and the "National" and "Acheson" Seals distinguish products of National Carbon Company, Inc.

KEEP YOUR EYE ON THE INFANTRY . . . THE DOUGHBOY DOES IT!

Allegheny-Ludlum Steel Corp. has purchased property at St. Louis from the *National Refining Co.*

A new organization of industrial designers and engineers has been formed in Chicago, with offices at 230 N. Michigan Ave., operating under the name of *Product Designers.* It offers a service of idea development, design, engineering, tooling and packaging. The principals are W. C. Nichols and Joseph Palma, Jr.

Kentucky's state fair grounds in Louisville, Ky. is humming with a new kind of activity. From a new and complete forging plant in buildings formerly housing live stock and other farm products, *Tube Turns, Inc.* is now shipping out a steady stream of forged aluminum heads for aircraft engines. The heads are made from a single bar of aluminum.

The *Optimus Equipment Co.* has been organized at Matawan, N. J., to design and manufacture a line of equipment for metal washing, rinsing, pickling, tumbling and drying operations.

House Organ Notes

Western Electric Oscillator, Western Electric Co., Sept. 1944.

This is a new house organ succeeding the former publication, "Pick-Ups." In explaining the reason for the change of name, an editorial explains: "A vacuum tube is nothing more than a particularly fine exhibit of the delicate craftsmanship of hands and machines in fashioning an object out of glass and metals, until it starts to oscillate. But when the electrons begin to flow, the very pulse and life of the universe are unleashed within its shiny glass canopy. The tube oscillates. Western Electric *Oscillator* takes its bow."

News for Members, American Iron & Steel Institute, Sept. 1944.

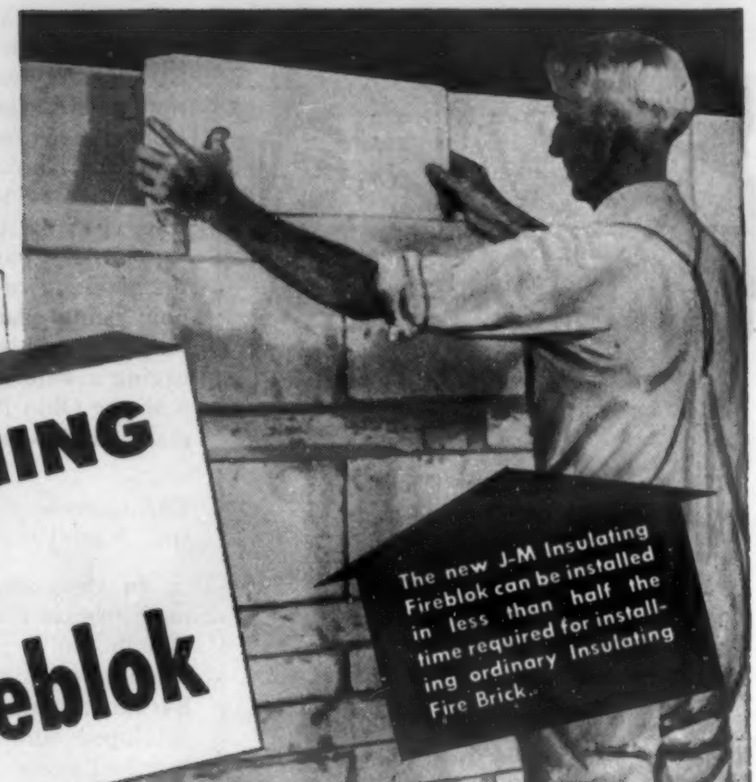
"Institute members played a part in furnishing information leading to the selection of the Yawata steelworks as the first Japanese target of the B-29's. Beginning early in 1942, the Institute has cooperated with various military and government war agencies in digging up information on Japan's steel industry. Many Institute members and other individuals who had been in Japan were consulted, and studies were made of published information and translated private documents to determine the location and relative importance of the various steel mills—large and small—in Japan and Manchuria."

The Bulletin, Youngstown Sheet & Tube Co., Sept. 1944.

"Water—water—water—enough to satisfy the needs of industrial plants. Enough

LESS DOWN TIME

FOR FURNACE RELINING with big, new J-M Insulating Fireblok



ONE OF THE NEW LIGHTWEIGHT Johns-Manville Insulating Fireblok covers more surface than five Insulating Fire Brick. So, when you reline furnaces with it, you can often get the job finished several times faster. Consider how many hours this can save you in down time, in maintenance crew time . . . and how much faster your furnaces can get back into profitable production.

The larger, more convenient size is the only difference between J-M's four new Insulating Fireblok and the four well-known J-M Insulating Fire Brick. Either size of these four grades of highly efficient refractory linings for use from 1600° F. to 2600° F., has these important advantages:

Easy cutting and fitting—J-M Fireblok can be easily cut with a saw and shaped with a rasp. Most special shapes can be either shop or field cut from standard slabs, reducing the inventory of special shapes.

Minimum of joints—the large size, compared to the standard fire brick unit, materially reduces the number and length of joints, resulting in a thermally more efficient construction.

Economical bonding—with reduced joint length Fireblok requires a minimum of air-set cement for bonding. (J-M 1626 Cement was especially developed for this use.)

Uses—Fireblok can be used wherever Insulating Fire Brick are recommended such as for heat-treating furnaces, flues, stacks, mains and similar equipment. Also for the lining of doors, suspended arches, and, when tapered, for sprung arches of exceptional stability.

Write for new booklet, IN-103A, on this J-M development. Johns-Manville, 22 East 40th St., New York 16, New York.

MOST WIDELY USED BACK-UP INSULATION BETWEEN 600°F. and 1900°F.—J-M SUPEREX

Made of high-quality, calcined diatomaceous silica and bonded with asbestos fiber, Superex combines all the desirable qualities of these two insulating materials. Result: High heat resistance and exceptional insulating efficiency. Ideal for boiler walls, furnaces, etc. Available in 3", 6", 9" and 12" by 18" and 36" blocks. Other lengths to order. Various thicknesses.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville INDUSTRIAL INSULATIONS

FOR EVERY TEMPERATURE . . . FOR EVERY SERVICE

water in the Mahoning River—some day when it is part of the Lake Erie—Ohio River waterways—to float barges carrying raw materials and finished products to and from the Valley's industrial plants. The waterway, known as 'The Canal,' has been a dream for 150 yr. We hope it becomes true when the United States starts its post-war projects—and the Canal is included in the program of the Federal Public Works now being planned. George Washington had correspondence with Thomas Jefferson urging a waterway connection of Lake Erie with the Ohio River. Water and dams will make the 150-yr. dream come true."

The Cathode Press, Machlett Laboratories, Inc., Sept. 1944.

"In designing a new electronic tube, mathematical calculations are invaluable, though only preliminaries. Then come many tests of various experimental tubes. But this cut-and-try method is wasteful. We developed our 'rubber model.' We use a stretched rubber sheet. At the high end is a model of the cathode of a proposed tube; at the other end the anode, or target of an X-ray tube, plate of an oscillator or rectifier. The slope between the two is proportional to the desired potential difference. With an electro-magnet a steel ball can be held in any position along the cathode, then released to roll under gravity to the anode, where the point it strikes can be observed and measured. This is an electro-mechanical analogy. With this rubber model technique, months have been shortened into days, weeks into hours."

The War Effort, The American Brass Co., Detroit, Sept. 1944.

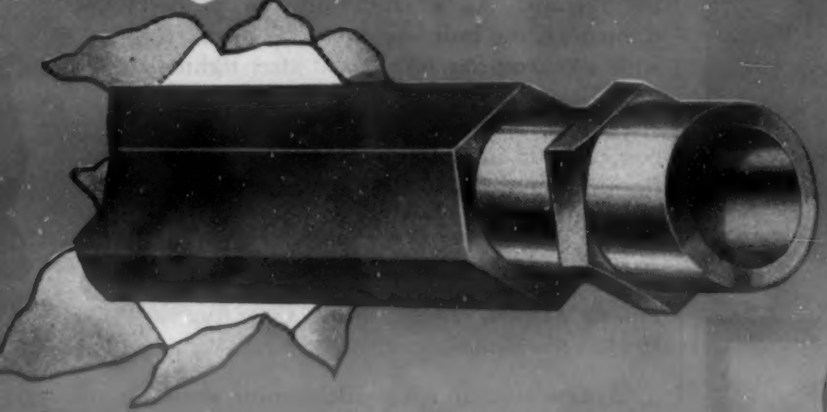
Under the heading, "Take Your Pick," the editor places the following side by side for comparison: "Historical experience has shown that the destruction and elimination of a foreign nationality is not in the least against the laws of life, provided that destruction and elimination are completed."—Werner Best, Nazi historian. "We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty, and the Pursuit of Happiness."—The Declaration of Independence.

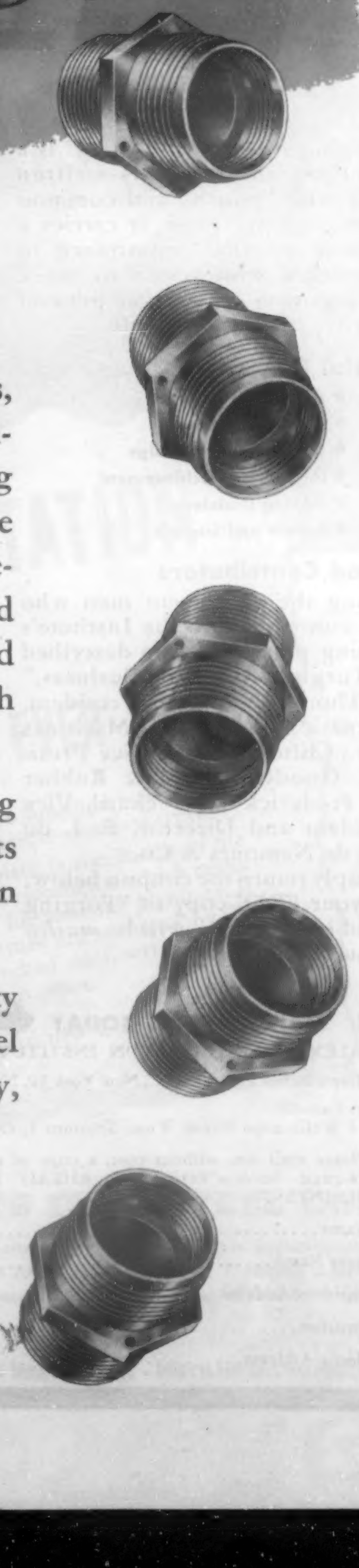
The Drum, Metals Disintegrating Co., Inc., Sept.-Oct. 1944.

"The demands for metal in this and future ages can only be met by the discovery of new sources or by the development of more complete and efficient methods of recovery from the ore. Within the past 20 yr., flotation processes for the separation of valuable mineral from unwanted gangue waste in the ore have yielded recoveries approaching 100%. In flotation processes, finely ground ore is mixed with a small amount of chemical, which causes the surface of the mineral material to become coated with an oily layer. The coated particles float on the surface of the water, where they can be skimmed off; the other component sinks. The phenomenon is well illustrated by the trick of making a greased needle float on water. Another example is

TIMKEN STAINLESS STEELS-

for free machining





For pump shafts, valve stems, nuts, bolts, capscrews and instrument parts where machining costs are an important factor — use free machining Timken Stainless Steels 303, 416, 430F and 440F. These 18-8 and straight chromium steels were developed especially for screw machine work. They cut rapidly and cleanly with a minimum build-up on cutting tools — and may be ground and polished to a fine smooth finish with less loading of the grinding wheels.

These free machining Timken Stainless Steels stay strong and bright under many of today's corrosive environments handling food, dairy and petroleum products, and in other applications in the process industries.

Give your products the advantages of strength, beauty and long life by specifying Timken Stainless Steels. Steel and Tube Division, The Timken Roller Bearing Company, Canton 6, Ohio.

TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

ALLOY STEELS

in the leafing of metal flake pigments in paints and varnishes. The metal flake particles have been chemically treated so that they are caused to float on the surface of the liquid area although they are heavier than the liquid."

Fasteners, American Institute of Bolt, Nut & Rivet Manufacturers, Vol. 1, No. 3.

"The 'feel' of a properly tightened nut and bolt can be acquired by practice, wrenching up the nut until the bolt seems to be pushing the wrench back where it came from. As a check on the proper tightening, the bolt length can be measured with a micrometer before and after tightening. For each inch of bolt length, the ideal amount of stretch in a properly tightened bolt is 0.003 in. Actually, a stretch ranging from 0.002 to 0.004 in. is satisfactory. Practice, checked by measurement of stretch, will develop the 'feel' for tightness."

Toledo System, Toledo Scale Co., August 1944.

"*System's* front cover illustration shows drums of sodium cyanide being filled over a Toledo portable scale, equipped with a photo-electric cut-off, and a chain tare device. Before starting the filling operation, the operator sets the scale beam to the sum of the net load of cyanide in the shape of 'eggs,' plus the average weight of the container. Any variation in the average weight of the container is compensated by adjusting the chain tare device. With this adjustment made, the operator presses a button starting the vibrator conveyor, which is operated at fast and slow speed. When the proper weight of materials has reached the container, the movement of the conveyor is stopped, automatically, by the photo-electric cut-off. The sodium cyanide imparts a hard, wear-resistant surface to gears."

Briefs on Associations, Promotions and Education

A sign of the times is that high frequency heating has so grown that a good-sized successful exposition of equipment and sustained lecture program can be conducted just for it alone—and on a strictly local attendance basis. From Sept. 25 to 28 the Wisconsin Electric Power Co. held such a demonstration at its Cold Spring shops, Milwaukee, ably directed by William H. Wagner. Operating installations of induction heaters for metals were exhibited by: Allis-Chalmers Mfg. Co., Induction Heating Corp., Lepel High Frequency Labs, Inc., Ohio Crankshaft Co., and Westinghouse; also, of dielectric heaters for non-metals by Federal Telephone & Radio Corp., Induction Heating Corp., and Westinghouse. Each evening two shifts of local engineers and production men heard lectures on induction heating by Dr. H. B. Osborne, Jr., of Ohio Crankshaft, and on


Significant facts for
POSTWAR planners
NO. 4

dielectric heating by J. W. Cable, of Induction Heating. Total attendance was 4000.

The American Foundrymen's Assn. has broadened its technical development program, whose functions in the main will include: Revision and publication of special books on specific phases of foundry practice, promotion and coordination of investigations now being carried on by the association, establishment of broader library facilities; also, of abstract and bibliographic services, development of material for presentation before the A.F.A. and other technical groups. New staff officers elected are: Secretary, R. E. Kennedy; director of the technical development program, N. F. Hindle, formerly assistant secretary; treasurer, C. E. Hoyt; assistant treasurer, Miss Jennie Reininga; business manager, Wm. W. Maloney, formerly assistant secretary.

Frank L. LaQue, Development and Research Div., International Nickel Co., has been elected chairman of the American Coordinating Committee on Corrosion. The committee was organized in 1938 to serve as a clearing house on American experience in corrosion. The committee comprises delegates from 17 technical societies.

Speaking of corrosion, the serious corrosion of pipes and fittings of high pressure condensate wells, costing the petroleum industry dearly, will be studied by Battelle Memorial Institute, Columbus, under auspices of the Natural Gasoline Assn. of America. Occurring in high pressure wells, 7,000 to 10,000 ft. deep, this corrosion creates an unusual hazard. Replacement in 90 days is often imperative.

The Magnesium Assn. held a two-day "first annual convention" at the Waldorf-Astoria Hotel, New York, in early October. Key officers were reelected, including, as president, Edward S. Christiansen, vice-president, Apex Smelting Co. Perry D. Helser is retained as secretary and permanent director.

John Otto Almen, head of Mechanical Dept. No. 1, General Motors Research Laboratories, has been awarded the Manly Memorial medal by the Society of Automotive Engineers for his work of increasing the working strength of metals and engine parts. Mr. Almen advocates shot blasting of engine parts to put metal in a compressive state.

The American Gas Assn. has elected J. French Robinson, president, East Ohio Gas Co., Cleveland, as its president. Because of the congested travel situation, the usual convention of the association was dispensed with this year.

Heavy demand for the 1942 Book of American Society for Testing Materials Standards and its Supplements, occasioned by the war production efforts, have necessitated advancing by a full year publication of the next book, to be issued in December, 1944, though normally issued November-December, 1945.

The American Society for Metals medal for the advancement of research was awarded to Robert Crooks Stanley, head of International Nickel Co. of Canada, Ltd., during the annual dinner at Cleveland Oct. 19. The medal was based on his

"pioneering leadership in the field of metals research."

Latin-American industrialists are invited to send groups of employees to the school of the Brown Instrument Co. in Philadelphia for free technical and practical instruction in precision industrial instrumentation. The school has been graduating over 400 students annually. The plan is described by its sponsor as "an honest approach to good will between Latin America and the U. S."

And speaking of schools, Westinghouse is teaching principles and applications of electronics in industry in a new ten-part training course covered by sound slide films, lesson books, quiz books and an instructor's manual. The course is available to engineering groups and individuals.

The North Jersey section, American Chemical Society, has created the Leo Hendrik Baekeland award to encourage creative talents of the younger American chemists. It will consist of $1,000 and a gold medal suitably inscribed.

Meetings and Expositions

INSTITUTE OF THE AERONAUTICAL SCIENCES, fall meeting. Dayton, Ohio. November 9-10, 1944.

NATIONAL STANDARD PARTS ASSOCIATION, annual fall meeting. Chicago, Ill. November 9-1_, 1944.

SOCIETY OF AUTOMOTIVE ENGINEERS, national fuels and lubricants meeting. Tulsa, Okla. November 9-10, 1944.

SOCIETY OF THE PLASTICS INDUSTRY, annual meeting. New York, N. Y. November 13-14, 1944.

AMERICAN PETROLEUM INSTITUTE, annual meeting. Chicago, Ill. November 13-16, 1944.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, annual meeting. New York, N. Y. November 15-18, 1944.

NATIONAL CHEMICAL EXPOSITION. Chicago, Ill., November 15-19, 1944.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, annual meeting. New York, N. Y. November 27-December 1, 1944.

NATIONAL EXPOSITION OF POWER & MECHANICAL ENGINEERING. New York, N. Y. November 27-December 2, 1944.

INSTITUTE OF METALS DIVISION and AMERICAN SOCIETY FOR TESTING MATERIALS, joint symposium on "Stress Corrosion Cracking." Philadelphia, Pa. November 29-30, 1944.

SOCIETY OF AUTOMOTIVE ENGINEERS, national air cargo meeting. Chicago, Ill. December 4-6, 1944.

NATIONAL AVIATION TRADES ASSOCIATION. St. Louis, Mo. December 6-8, 1944.

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By Edwin F. Cone

New Steel Industry Data

Some statistics never before compiled and published have recently been made public by the American Iron and Steel Institute and are quite interesting and informative. They refer only to 1943.

The consumption of fluxes in steel making furnaces last year was 6,534,086 net tons of which 224,250 tons were fluorspar; 5,117,629 tons, limestone; 936,872 tons, lime; and 255,335 tons, other fluxes. Total coal consumption in 1943 by the steel industry was 90,904,790 tons of which about 99.1% was bituminous. The steel industry last year consumed 18,380,000 kw. hr. of electric power, of which 11,212,000 kw. hr., or nearly 61%, was purchased.

In melting, heating and annealing and all other furnaces, the industry used in 1943 2,109,425,474 gal. of fuel oil, 226,784,000 gal. of tar and pitch, and 868,172,000 cu. ft. of natural gas.

The magnitude of the industry as well as its effect on our economy is reflected by these data.

Reemploying War Veterans

The Carnegie-Illinois Steel Co. reports that it has already (September) reemployed more than 4000 veterans of the present war. About 43,000 employees of the company have gone into the armed services. How many of the former employees now serving will return is of course not known, says J. L. Perry, president, but "it is our wish that all of them return and that all of them who do return will want to return to employment with our company."

Another company, Inland Steel, states that most of the employees on leave of absence with the armed forces will return to work when demobilized. Already 225 have returned, 8 of them wounded veterans who have become adjusted to civilian duties again.

Post-War Aluminum Output

Production of aluminum in the post-war period will decline to about one-third of present capacity or to approximately 900,000,000 lb., according to estimates in Washington as reported by Walter Jannsen, chief of the metals and minerals unit of the Bureau of Domestic Commerce. This estimate is about three times greater than the peak peacetime output in 1939.

Induction Heating

New developments in the high frequency induction heating field continue to appear. The Tocco Div. of the Ohio Crankshaft Co. has introduced a new type 2-station radio frequency electronic heating machine, and a new super-silent water-cooled motor generator set for use in 3000 to 9600-cycle units. The new electronic machine has a normal frequency of 450,000 cycles and a 20-kw. output capacity. The new water-cooled motor generator set is claimed to now make possible the use of high-frequency-induction heating in locations which, because of high heat and grimy shop conditions, were denied the advantages of this heat treatment method.

Some Uses for Tantalum

Tantalum metal is being used in many unusual ways, says the *Ohmite News.* It is not irritating to living tissues, is ductile, malleable and resists corrosion. Tantalum wire so fine that a surgeon feels for it rather than sees it is now being used to repair nerves and to make surgical stitches where facial appearance is important.

Steel Output Gaining

Although the steel ingot output for August was a little below that for July, the total for the first 8 mo. of this year has been higher than in the same period in 1943, a record year. To Sept. 1, this year, the total has been 60,005,971 net tons, or 7,500,731 tons per mo. For the same 8 mo. in 1943 the total was 58,880,791 tons, or 7,360,099 tons each month. Should this ratio keep up, the 1944 total will make a new record—it all depends on the progress of the war.

Pig Iron Output

Statistics for July, issued by the American Iron and Steel Institute, show that pig iron and ferroalloy output is about maintaining full volume. The July total was 5,156,814 net tons making the average per month to Aug. 1, 5,234,062 tons. This compares with 5,148,108 tons per mo. for all of 1943 and 4,998,513 tons per mo. for all of 1942.

Copper After the War

The annual post-war consumption of copper is estimated by Dr. W. R. Ingalls, director of the American Bureau of Statistics, as about 1,265,000 tons. This authority divides this total into about 850,000 tons of new copper and 415,000 tons of old. This total consumption would be 18 lb. per capita of an expected population of 140,000,000 at the middle of 1945. In the potential distribution of this total, electrical manufactures heads the list at 250,000 tons, with building second at 225,000 tons. He assumes a continuance of the 4¢ tariff and a freezing or locking up of all the holdings as stockpile material. These facts appear in an article in *Mining and Metallurgy* for September.

Activities of A.F.A. Broadening

Broadening the technical scope of the American Foundrymen's Association is a new development in that progressive society. At a recent meeting of the board of directors, N. F. Hindle, formerly assistant secretary, was elected director of the Technical Development Program. Some of the functions of this new department include: Revision and publication of special books and pamphlets; collection and correlation of published and unpublished data; promotion and coordination of investigations now being carried on by the A.F.A.; establishment of broader abstract and bibliological services; and development of material for presentation before Association chapters and other engineering and technical groups. An advisory committee will work with Mr. Hindle.